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DAVID W. TAYLOR NAVAL SHIP RESEARCH AND DEVELOPMENT CENTER

Bethesda, Md. 20084

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PREDICTION OF RESISTANCE AND PROPULSION CHARACTERISTICS FOR A SMALL WATERPLANE AREA TWIN HULL (SWATH) FORM REPRESENTED BY MODEL 5287.

BY

10 A. C. M. LIN, L. B. CROOK [redacted] L. O. MURRAY

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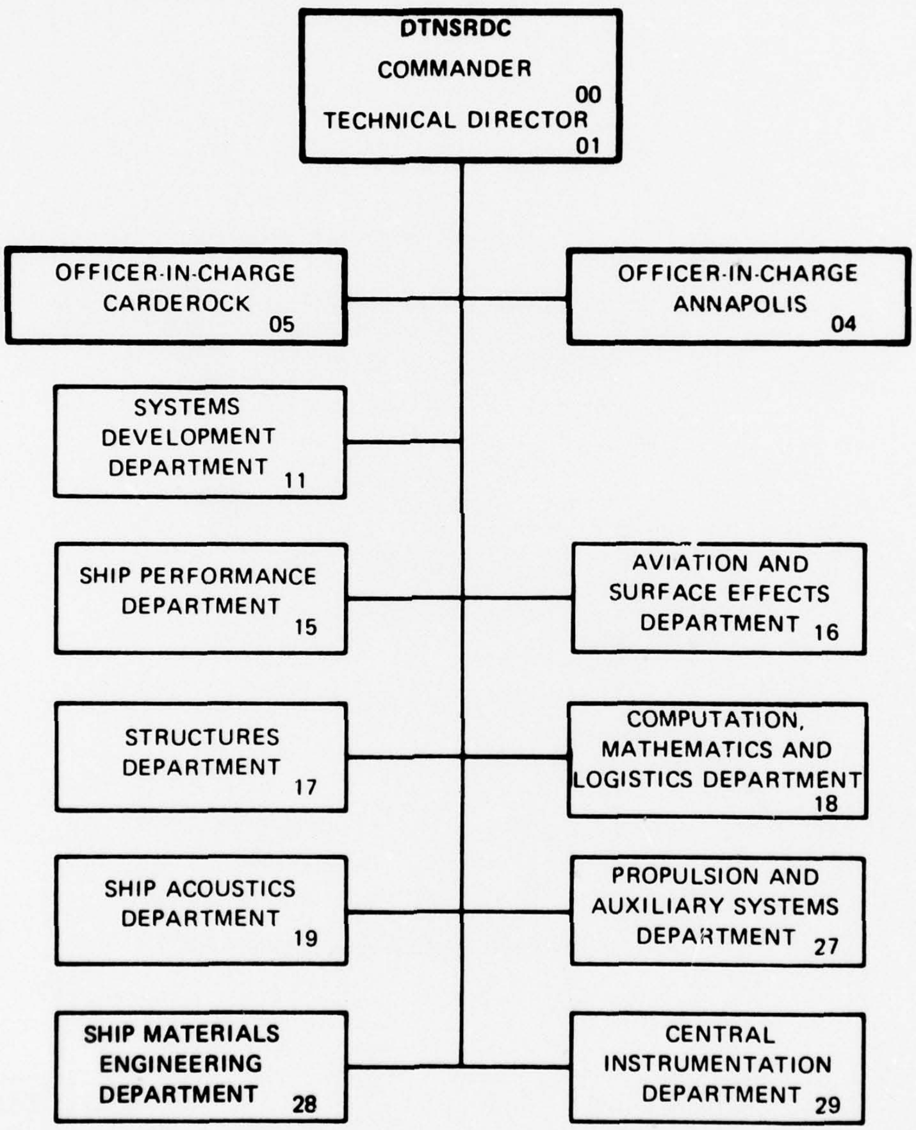

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The Naval Ship Research and Development Center (DTNSRDC) undertook a program to find an optimum hull form of low waterplain area. This program evaluated the cambered-hull effect on resistance and propulsion for a small waterplane area twin hull (SWATH IV). This experimental evaluation was divided into six sections to investigate the affects of variations in draft, propeller diameter, correlation allowance, one propeller driving - one windmilling, change of hull camber from inboard to outboard, and in experimental techniques using free to trim and heave, free to heave and captive modes. The effects of next Page

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of draft on resistance and propulsion are sizeable in the low speed range, but are not significant above a speed length ratio of 1.0. The propeller diameter doesn't affect hull efficiency as varying speed does. The propulsion coefficients are not significantly changed by correlation allowance. Hull camber inward was superior for both resistance and propulsion. The powering characteristics of Model 5287 was dependent on interference, sinkage and trim effects. The technique for conducting the experiments consequently is of prime importance.

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INTRODUCTION

The Naval Ship Research and Development Center (NSRDC) has recently undertaken a program to find an optimum hull form of low waterplane area hull forms. A new version of hulls and struts cambered inboard has been established based on previous designs and experimental data. To evaluate the cambered-hull effect on resistance and propulsion, Model 5287, representing a small waterplane area twin hull (SWATH IV), was built of mahogany to a linear ratio of 20.4 in accordance with lines designed at NSRDC. Ship and model dimensions are given in Figures 1 and 2. The tabulated coefficients and sectional area curves apply to a single hull and strut below the 28-foot waterline. Abbreviated body lines and plans are presented in Figures 3 and 4. Both plans are drawn to show the amount of camber. Photographs of the model are presented in Figures 5 through 8.

EXPERIMENTAL PROCEDURE

The demihulls were rigidly connected by two transverse boards on top of the struts at Stations 6 and 14, respectively. The hull was spaced 75 feet, full-scale, between the centers of hulls and struts at midships. The towing strut of aluminum-framed structure, with vertical, adjustable steel-bar tow post, was connected directly to the carriage floating girder on top and hinge-connected to each of the two arms at the center of the hull. The propulsive unit and the force measuring devices, gearboxes, RPM counters and motors were pre-installed in the submerged hull.

A pair of wooden troughs were fitted on top of the struts to facilitate the movement of ballast in the longitudinal direction for model experiments in the free-to-heave condition only.

The model was ballasted to full-scale conditions corresponding to 4,270, 3,960, and 3,730 tons at drafts of 32, 28 and 25 feet, respectively. Experiments were conducted to evaluate the resistance and propulsion characteristics of hull configurations at various conditions and using different experimental techniques as tabulated in Table 1.

PRESENTATION OF DATA

The data collected during the resistance experiments are presented in Figures 9 through 12 in the form of residuary resistance coefficient (C_r) versus the speed-length ratio ($V/\sqrt{L_{eff}}$) and ship speed in knots, and effective horsepower versus ship speed in knots. The data from the propulsion experiments are presented in Figures 13 through 25. In the expansion of these data, the I.T.T.C. friction formulation, in conjunction with various correlation allowances (ΔC_f), was used. Since neither the length of the underwater hull nor the strut length would accurately represent the effective length of the hull for the purposes of computing frictional resistance, it was assumed that

$$\text{Effective length } (L_{eff}) = \frac{\text{Strut Wetted Surface (strut length)}}{\text{Total Wetted Surface}} + \frac{\text{Hull Wetted Surface (hull length)}}{\text{Total Wetted Surface}}$$

Measurements of change of level were recorded during model experiments. Curves of trim, and change of level, bow and stern, versus speed are given in Figures 26 through 29. Wave profiles are given in Figure 30.

The propeller dimensions and open-water characteristics for the model

TABLE 1 - EXPERIMENT PROGRAM FOR SWATH IV

REPRESENTED BY MODEL 5287

	DRAFT - IN FT	32	28			25
	CONDITION	FREE TO TRIM AND HEAVE	FREE TO TRIM AND HEAVE	FREE TO HEAVE	CAPTIVE	FREE TO HEAVE
	DESCRIPTION	EXPERIMENT NUMBER				
	EHP	1	3	7	11	9
SHP	SHP - Propeller # 1	2	4	8	12	10
SHP	SHP - Propeller # 2				13	
SHP	SHP - Propeller # 3				14	
SHP	OVERLOAD $\Delta C_f = 0$				15	
SHP	OVERLOAD $\Delta C_f = 0.0008$				16	
SHP	OVERLOAD $\Delta C_f = 0.0012$				17	
SHP	WINDMILLING PROPELLER # 1				18	
SHP	WINDMILLING PROPELLER # 3				19	
EHP	SWITCH HULLS REVERSE CAMBER				20	
SHP	SWITCH HULLS REVERSE CAMBER				21	
	TRIM AND TRIM MOMENT	1 - 2	3 - 4	7 - 8		9 - 10
	WAVE PROFILE			7	11	

NOTE

(1) All tests are at 75 ft hull spacing center to center at the midship
(2) Propeller # 1 - 16.4 ft diameter Propeller # 2 - 13.0 ft diameter
Propeller # 3 - 19.3 ft diameter

propellers (NSRDC Nos. 3217 and 3218, 4415 and 4416, 585 and 586) used in the experiments are presented in Figures 31 through 36. These propellers represent full-scale propellers having diameters of 16.4, 13.0, and 19.3 feet, respectively.

DISCUSSION

The discussion is divided into six sections to describe the results brought about by variations in draft, propeller diameter, correlation allowance, one propeller driving - one windmilling, interchange of hulls port and starboard to change the hull camber from inboard to outboard, and in experimental techniques (towing or propelling free to trim and heave, free to heave, or captive).

1. Draft Variations

A. Residual resistance coefficients (C_r)

Curves of residual resistance coefficients at three different drafts are presented in Figure 9. A tabulation of these data at even speeds is listed in Table 2. It should be noted that the experiments at the three different drafts were not all conducted using the same experimental technique due to lack of time and funds. As explained in Section 6 of the discussion, there can be some significant effects in the results due to changes in techniques. It is possible, therefore, to compare the results for the 32-foot draft, free-to-trim-and-heave, with those for the 28-foot draft using the same technique. Similarly, C_r values for the 25-foot draft, free-to-heave, are compared to those for the 28-foot draft, free-to-heave. From Table 2, it may be seen that differences in C_r due to draft variations are largest at very low speeds. From 22 knots up, the differences are very small. In the lower speed range, it appears that draft (depth of submergence of main hulls) is quite important up to $V/\sqrt{L}$ of 1.0, about 16 knots.

TABLE 2

The Ratio of Residual Resistance Coefficient

of Model 5287 at Three Different Drafts

SPEED IN KNOTS	Free-to-Trim-and-Heave $\frac{(C_r)\ 28\text{-ft draft}}{(C_r)\ 32\text{-ft draft}}$	Free-to-Heave $\frac{(C_r)\ 28\text{-ft draft}}{(C_r)\ 25\text{-ft draft}}$
12	1.24	0.57
14	1.61	0.88
16	1.17	1.01
18	1.20	1.15
20	1.11	0.84
22	0.99	0.95
24	1.04	0.98
26	1.01	0.98
28	1.02	0.99
30	1.00	0.99
32	0.98	1.01
34	0.98	0.93

B. Propulsion Experiments

Results of the propulsion experiments, shown in Figures 13 through 16, indicate that most of the major differences in the propulsive coefficients are in the lower speed range where test accuracy is a problem. At higher speeds, the differences at the various drafts are comparatively small. Thrust deduction does seem to vary somewhat more noticeably than for conventional single hulls. Table 3 presents a comparison of relative powering requirements using SHP/ton as a figure of merit. Again, the differences due to draft are quite small at the higher speeds.

TABLE 3

SHP per Ton of Displacement at Different Drafts and Speeds

	FREE TO TRIM AND HEAVE		FREE TO HEAVE	
SPEED KNOTS / DRAFT, FT.	32	28	28	25
15	1.03	0.97	1.07	1.13
20	2.43	2.32	2.35	2.25
25	10.14	9.64	9.14	8.95
30	16.40	16.52	15.30	15.01
35	18.33	18.64	17.02	16.78

2. Variations in Propeller Diameter

One of the questions which arose as the planning of this project progressed, was whether the wake and thrust deduction factors would change with an increase in propeller diameter. A series of stock propellers was selected with varying diameters equivalent to 13.0, 16.4, and 19.3 feet, full-scale. The results of the propulsion experiments are presented in Figures 17 through 19. Open water characteristic curves for the propellers are shown in Figures 32, 34 and 36. It should be noted that the pitch ratios (P/D) for the three sets of propellers are different. Consequently, the propeller efficiency (e_p) in the operating condition is affected and similarly, the propulsive coefficient (EHP/SHP). The factors of interest in these experiments, as previously stated, were thrust deduction and wake as compared in Table 4.

TABLE 4

EFFECTS OF CHANGING PROPELLER DIAMETER
ON THRUST DEDUCTION AND WAKE FRACTIONS

SPEED IN KNOTS	PROPELLER DIAMETER IN FEET								
	13.0			16.4			19.3		
	t	w_T	e_h	t	w_T	e_h	t	w_T	e_h
15	0.11	0.245	1.135	0.11	0.20	1.10	0.08	0.155	1.09
20	0.15	0.105	0.95	0.11	0.075	0.965	0.06	0.08	1.02
25	0.115	0.08	0.95	0.075	0.055	0.985	0.05	0.065	1.015
30	0.135	0.085	1.06	0.04	0.06	1.025	0.01	0.045	1.034

Typically, as propeller diameter is increased thrust deduction fraction decreases, but so does wake fraction to the point where hull efficiency is not changed as much as desired. As seen above, there are rather significant changes in these hull-propeller interaction factors as speed changes, which is again typical of SWATH forms.

3. Correlation Allowance Effect

Experiments were conducted at four correlation allowances for use in design calculations. All the experiments were conducted at the same draft - 28 feet; the same operating condition - captive; the same hull spacing - 75 feet between the center of hulls at midships. The experiments were conducted in an extensive speed range as shown in Figures 17,and 20 through 22, but the last two experiments with higher correlation allowances could not reach the design speed of 32 knots due to loading limitations in the instruments. As might be expected, there was little difference in the propulsion coefficients other than the normal change in e_p due to propeller loading as shown in Table 5 for a speed of 30 knots.

TABLE 5

VARYING CORRELATION ALLOWANCES

30 KTS

	0.0004	0	0.0008	0.0012
EXPERIMENT NO.	12	15	16	17
EHP/SHP	0.765	0.765	0.745	0.745
e_p	0.725	0.730	0.715	0.715
e_h	1.025	1.04	1.03	1.03
e_{rr}	1.035	1.01	1.01	1.02
t	0.04	0.04	0.04	0.04
w_T	0.06	0.075	0.065	0.06

4. Comparison Between Two Diameters of Propellers with One Shaft Windmilling

These experiments were conducted at the 28-foot draft, the same hull spacing of 75 feet, captive with the starboard propeller windmilling. The purpose of these experiments was to provide information for the machinery designers. The experimental results are presented in Figure 22 for the 16.4-foot diameter propellers, and in Figure 23 for the 19.3-foot propellers. It should be noted that the data are for the driving propeller only. Also, the gear train in the model creates considerably more friction than would be expected from a full-scale machinery plant. It should be further noted that the results with the 16.4-foot diameter propellers appear more reasonable than those from tests with the larger propellers.

5. Comparison Between Two Hull Configurations - one with camber inboard and the other with camber outboard

The purpose of this experiment was to evaluate the effect of camber on the hulls. The experiments were conducted at the same operating condition, draft, and hull spacing except the hulls were changed from port to starboard and vice versa. The rotation of propellers was in the same direction - outward. Resistance and propulsion experiments were conducted for both configurations as given in Figures 10, 12, 17, and 25. The comparison between these two configurations will be discussed in the following sections:

(a) Residual Resistance Coefficients (C_r)

The shape of the residual resistance coefficient curves for both experiments generally is similar. The major hump is at the speed-length ratio of 1.6, and the slope of the curves drops sharply as the speed-length ratio is increased. These curves are presented in Figure 10. They indicate that the

configuration with camber outboard has larger residual resistance coefficients (C_r) at lower speed, and that the difference is reduced considerably at the speeds over 30 knots as shown in the following table.

TABLE 6

COMPARISON OF RESIDUAL RESISTANCE COEFFICIENT

FOR TWO HULL CONFIGURATION

SPEED IN KNOTS	$\frac{\text{EXPERIMENT \#20 CAMBER OUTBOARD}}{\text{EXPERIMENT \#11 CAMBER INBOARD}}$
10	1.89
12	1.62
14	2.02
16	1.06
18	1.08
20	1.49
22	1.20
24	1.13
26	1.09
28	1.05
30	1.04
32	1.01
34	1.01
36	1.02
38	1.03
40	1.02

From Table 6, it would appear that differences in camber would not be significant for design speeds in excess of 30 knots. If the cruising speed fell in certain ranges, it is rather obvious that the difference is substantial.

(b) Effective Horsepower

The above remarks apply also to EHP at the high speeds to an even greater degree as differences become infinitesmal as shown in Figure 12.

(c) Propulsion Experiments

The resistance experiment indicates that the camber inboard version requires less effective horsepower than the camber outboard version at a comparable speed. The propulsion experiment results depict the same order, and Figures 17 and 25 present these results. The data in these figures indicate that the propulsive coefficient of the inboard camber version is about 4 percent higher than the other version. This is due to changes in e_h and e_{rr} as e_p does not change measurably. It may be noted that there is a 3 percent change in w_T.

6. Experiments Using Different Techniques

If it could be shown that interference effects between the hulls were insignificant, then it would be economically desirable to build and conduct experiments with a single hull rather than a twin hull. Experiments were conducted at the same draft and hull spacing using the following operating conditions:

(A) Model free to trim and heave

(B) Model free to heave (trim held constant by moving ballast)

(C) Model captive (fixed in trim and heave)

The results of the above experiments are presented in Figures 9, 11, 14, 15, and 17. In order to illustrate the differences among the experiments, the following items will be discussed:

(a) Residual Resistance Coefficient (C_r)

The results of resistance experiments using the three techniques are presented in Figure 9. The curves have the same general shape with the hump appearing at the speed-length ratio of 1.6. These curves indicate that the condition free-to-trim-and-heave gives the highest

value of residual resistance, free-to-heave is the next, and captive is the lowest. Table 7 gives the tabulated values in ratio of residual resistance coefficient ratios between the condition of free-to-trim-and-heave against free-to-heave and captive.

TABLE 7

Residual Resistance Coefficient Comparison

SPEED IN KNOTS	$\frac{V}{\sqrt{L_{eff}}}$	$\frac{(C_r)\ \text{FREE TO TRIM \& HEAVE}}{(C_r)\ \text{FREE TO HEAVE}}$	$\frac{(C_r)\ \text{FREE TO TRIM \& HEAVE}}{(C_r)\ \text{CAPTIVE}}$
10	0.61	1.026	1.813
12	0.73	1.091	1.712
14	0.85	1.161	1.425
16	0.98	1.000	1.036
18	1.00	1.006	1.006
20	1.22	1.131	1.490
22	1.34	1.093	1.199
24	1.47	1.048	1.123
26	1.59	1.027	1.092
28	1.71	1.025	1.064
30	1.83	1.024	1.053
32	1.95	1.031	1.051
34	2.08	1.041	1.050

From Table 7, it is apparent that it would be very difficult to predict the free-to-trim-and-heave results from either of the other two conditions. The captive condition in particular is vastly different from the others.

(b) Propulsion Experiments

The propulsion experiment results are presented in Figures 14, 15, and 17. In addition to these figures, Table 8 shows tabulated horsepower

TABLE 8 - COMPARISON IN SHAFT HORSEPOWER AND PROPULSION COEFFICIENTS IN THREE CONDITIONS

SPEED IN KNOTS	Free to Trim and Heave			Free to Heave			Captive		
	SHP	EHP/SHP	e_r	SHP	EHP/SHP	e_p	SHP	EHP/SHP	e_p
10	1,100	.750	.750	1,110	.740	.750	960	.780	.750
15	3,840	.805	.745	4,220	.755	.745	3,820	.805	.740
20	9,200	.780	.750	9,290	.745	.750	8,330	.770	.750
25	38,700	.700	.713	36,200	.723	.723	34,600	.730	.720
30	65,400	.695	.725	60,600	.735	.725	57,100	.765	.725
32	73,800	.695	.730	67,400	.745	.730	63,400	.785	.730
	e_h	e_{rr}	RPM	e_h	e_{rr}	RPM	e_h	e_{rr}	RPM
10	1.045	.960	52	1.015	.97	53	.955	1.095	52
15	1.060	1.025	78	1.060	.955	79	1.035	1.055	78
20	1.015	1.025	108	.975	1.015	109	.965	1.060	108
25	.960	1.008	157	.961	1.048	158	.980	1.030	154
30	.945	1.015	190	.990	1.025	187	1.025	1.035	183
32	.945	1.005	200	1.000	1.025	195	1.035	1.035	192
	t	w_T	w_Q	t	w_T	w_Q	t	w_T	w_Q
10	.090	.125	.140	.090	.105	.110	.180	.140	.115
15	.100	.150	.145	.080	.130	.145	.140	.170	.150
20	.070	.080	.075	.090	.070	.065	.110	.075	.060
25	.098	.060	.050	.071	.031	.015	.075	.060	.045
30	.090	.035	.025	.050	.040	.030	.035	.060	.045
32	.080	.030	.025	.050	.045	.040	.030	.065	.050

and coefficients which give the general picture among the three different experimental techniques. There is an obvious difference in shaft horsepower and propulsive coefficient for the various operating conditions. Again, as for the comparison of residual resistance coefficients, the differences in the results obtained with the three techniques are too sizable to ignore.

There is a very strong dependence on speed which might infer that both interference and trim effects are significant, and cannot be estimated in advance with any precision. Figures 26 and 27 present change in level data for both resistance and propulsion experiments at the 32-foot and 28-foot drafts, respectively. There is a marked change in trim between these two types of experiments which is unusual as compared to conventional displacement hulls. The additional trim encountered when propelling the model is substantial.

GENERAL COMMENTS

It is understood that SWATH IV was designed, as was SWATH III, with a size and speed appropriate to an escort ship. As with SWATH III, it is of interest to compare the predicted performance of SWATH IV with a single hull form from the Taylor Standard Series, assuming that the Taylor hull is the same displacement and operates at the same speed as the SWATH IV configuration. From historic data available at the Center, it is possible to set limits on hull coefficients for previous ships which have been used for escort duties. From these coefficients, dimensions can be derived for length, beam and draft. Wetted surface and residual resistance coefficients can be obtained from the Taylor contours presented in

reference 1 . A reasonable value for appendage resistance and EHP/SHP has been selected from past data. With the concession that the assumptions as listed are valid, the comparison can be made in Table 9.

As noted in the discussion on SWATH III, the Taylor form is not necessarily the best design that could be obtained with modern methods. At the speed-length ratio listed, it is not uncommon for better hull forms to be 5 to 10 percent less resistant than the equivalent from the Standard Series.

CONCLUSIONS

1. The effects of varying draft on resistance and propulsion are sizable up to a speed of 20 knots, but are not very significant above that speed.

2. Varying propeller diameter does not affect hull efficiency as much as varying speed does.

3. There is no significant change in the propulsion coefficients due to changing correlation allowances as anticipated.

4. The hull configuration with camber inward is superior to that with camber outward for both resistance and propulsion. As the configuration was designed with camber inward, the results are those hoped for by the designer.

5. The powering characteristics of the SWATH configuration is highly dependent on interference, sinkage and trim effects. Consequently, the technique for conducting the experiments is of prime importance. It is difficult to see how reasonable propulsion results can be obtained with a captive model. If it is assumed that trim will be controlled by either external or internal means, then presumably the free-to-heave technique is a valid one.

References are listed on page 17.

TABLE 9

	SWATH IV	SINGLE HULL TAYLOR FORM	
Speed, knots	32	32	
Displacement, tons S.W.	3960	3960	
LWL, feet (effective length)	266	407	$(V/\sqrt{LWL} = 1.59)$
Beam, feet	-	45.22	$(L/B = 9)$
Draft, feet	28	15.07	$(B/H = 3)$
Wetted Surface, $feet^2$		19025	
C_P		0.624	
C_M		0.8	
$EHP_{bare\ hull}$	50200	33950	
Appendage Allowance	2%	20%	
EHP appended	51200	40740	
EHP/SHP	0.73	0.65	
SHP	70140	62670	
$EHP_{SWATH/TAYLOR}$	1.26		
$SHP_{SWATH/TAYLOR}$	1.12		

REFERENCES

1. Gertler, Morton, "A Reanalysis of the Original Test Data for the Taylor Standard Series," DTMB Report 806 (1954)

SHIP AND MODEL DATA
FOR A SMALL WATERPLANE AREA TWIN HULL (SWATH IV)

REPRESENTED BY MODEL 5287

DIMENSIONS				
	HULL		STRUT	
	SHIP	MODEL	SHIP	MODEL
LENGTH (LOA) FT	287.58	14.10	—	—
LENGTH (LWL) FT	—	—	226.7	11.12
BEAM (B_{IX}) FT	18.00	0.88	8.0	0.39
DRAFT (H) FT	18.00	0.88	10.0	0.49
DISPL. IN TONS	1,570 SW	0.18 FW	410.0 SW	0.05 FW
W.S. IN SQ FT	13,800	33.18	5,110.0	12.28
DESIGN V IN KTS	32	7.08	32	7.08

COEFFICIENTS		
	HULL	STRUT
C_B	0.595	0.748
C_P	0.758	0.758
C_x	0.785	0.987
C_W	—	0.740
C_{PF}	0.80	0.75
C_{PA}	0.71	0.77
C_{PE}	0.78	0.60
C_{PR}	0.66	0.81
L_F/L	0.45	0.44
L_P/L	0.13	0.22
L_R/L	0.42	0.34
L/B_X	16.02	28.26

NOTE:
1. The value of displacement and wetted surface are for one hull and strut only.
2. The total wetted surface for the combination of hull and strut is 17,540 sq ft. The hull masked area is excluded.
3. The total draft used here is 28 foot ship, 1.37 feet model.
4. The linear ratio (λ) is 20.4

Figure 1

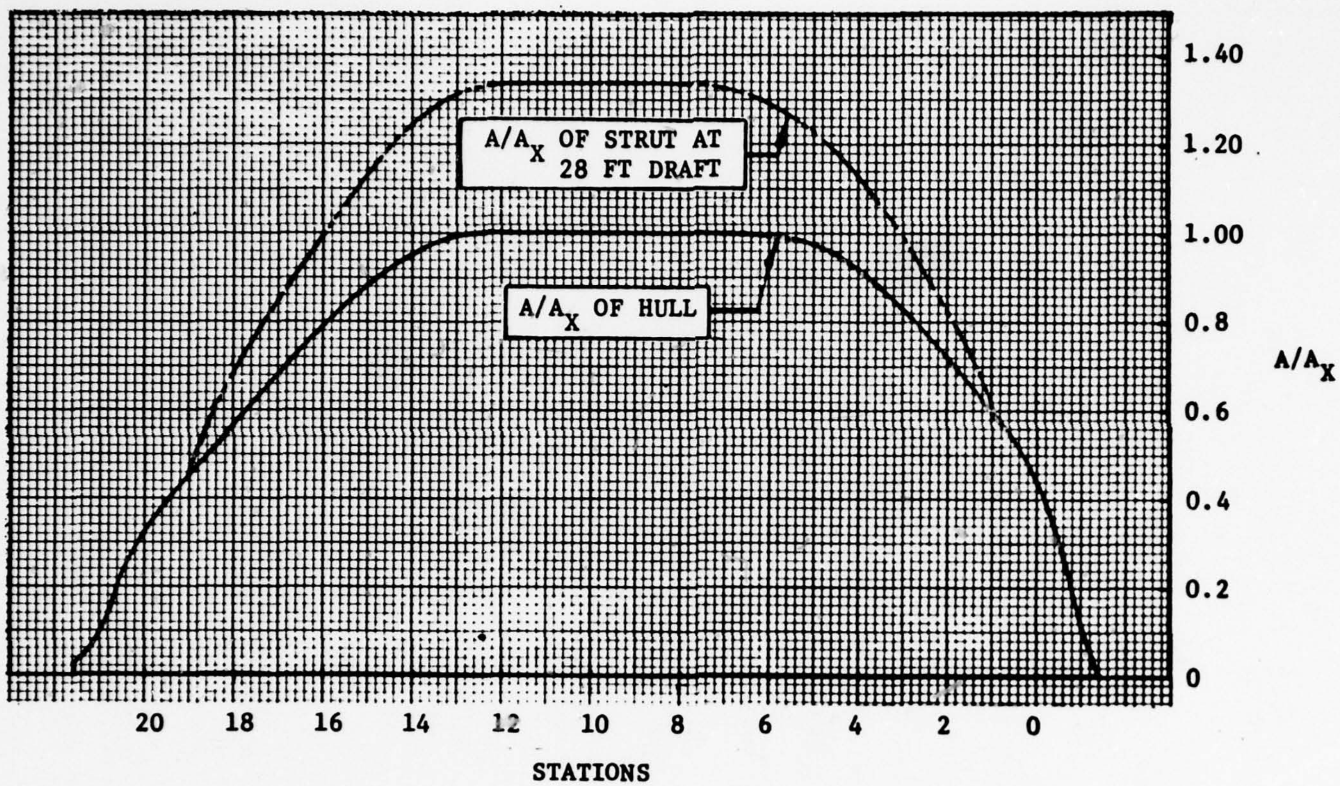


Figure 2 - Sectional Area for Single Strut and Hull of SWATH IV Represented by Model 5287

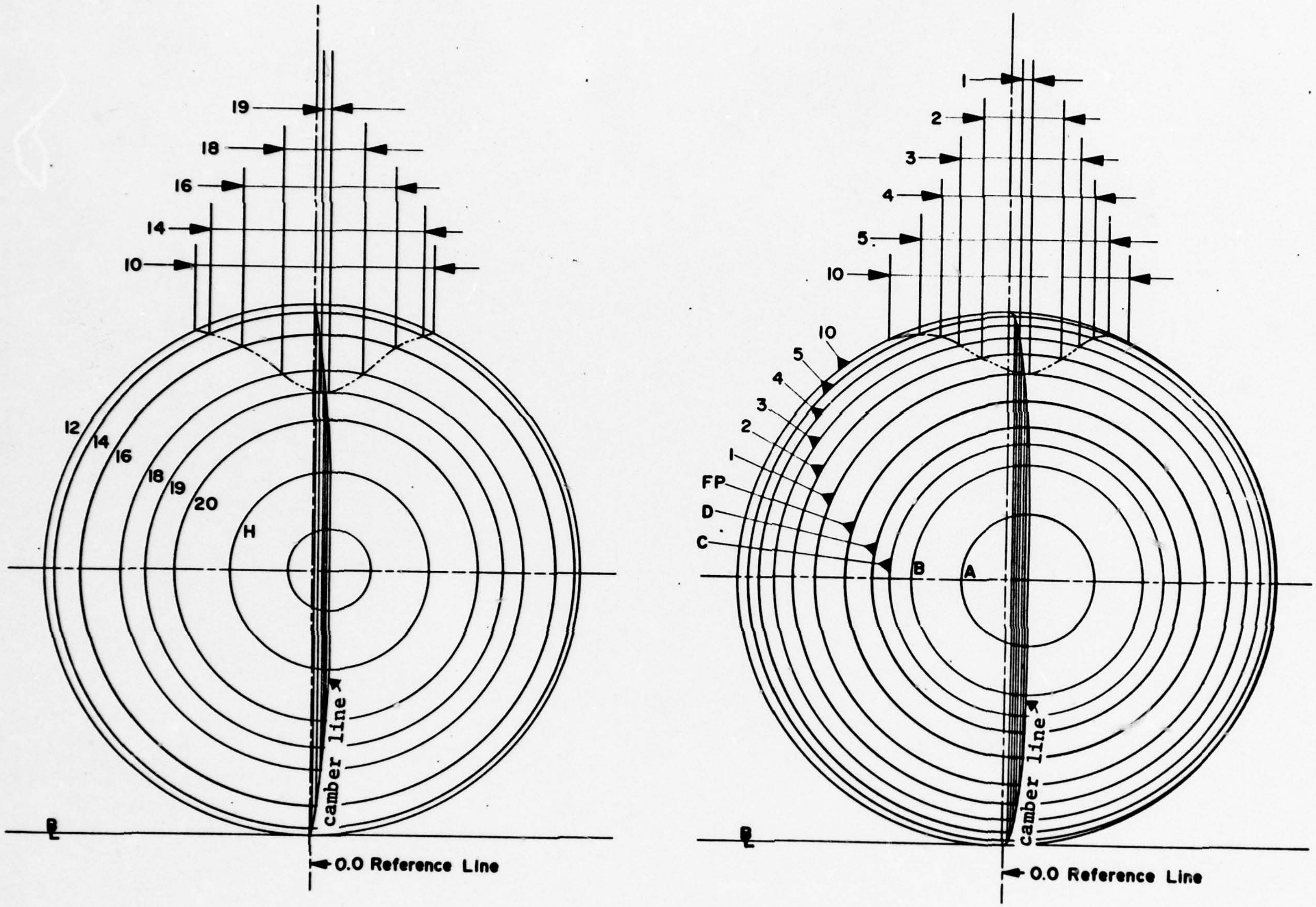
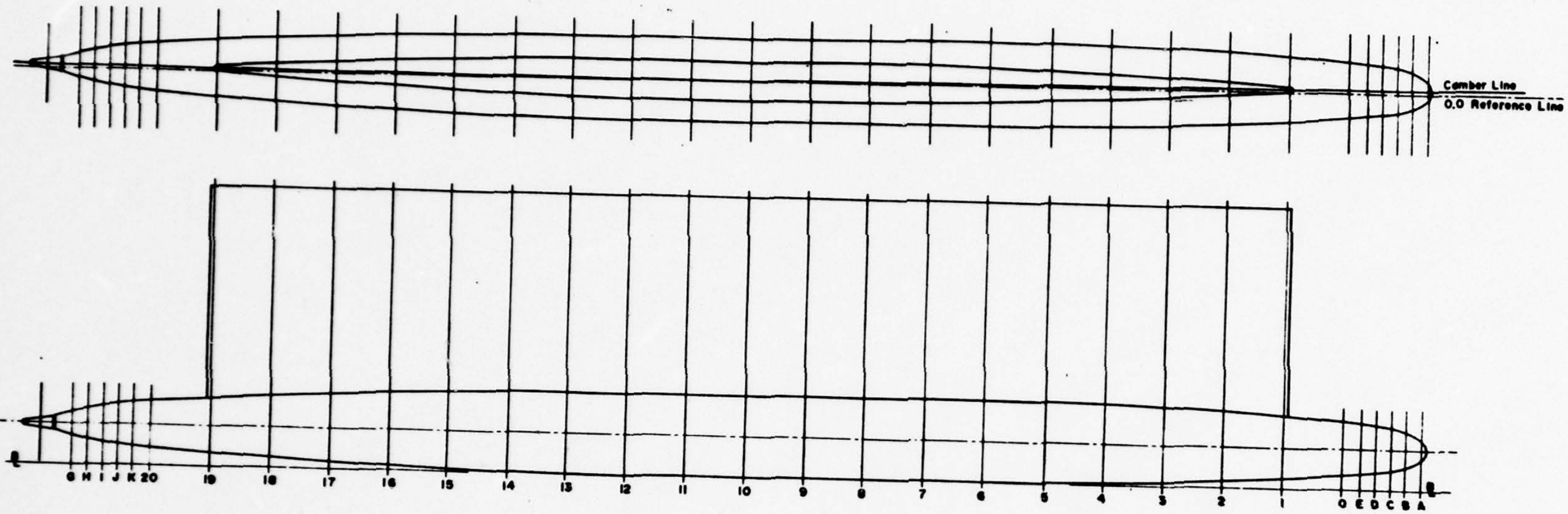


Figure 3 - Abbreviated Body Plan for SWATH IV
Represented by Model 5287



SWATH IV
MODEL 5287

Figure 4 - Abbreviated Lines and Profile for SWATH IV Represented by Model 5287

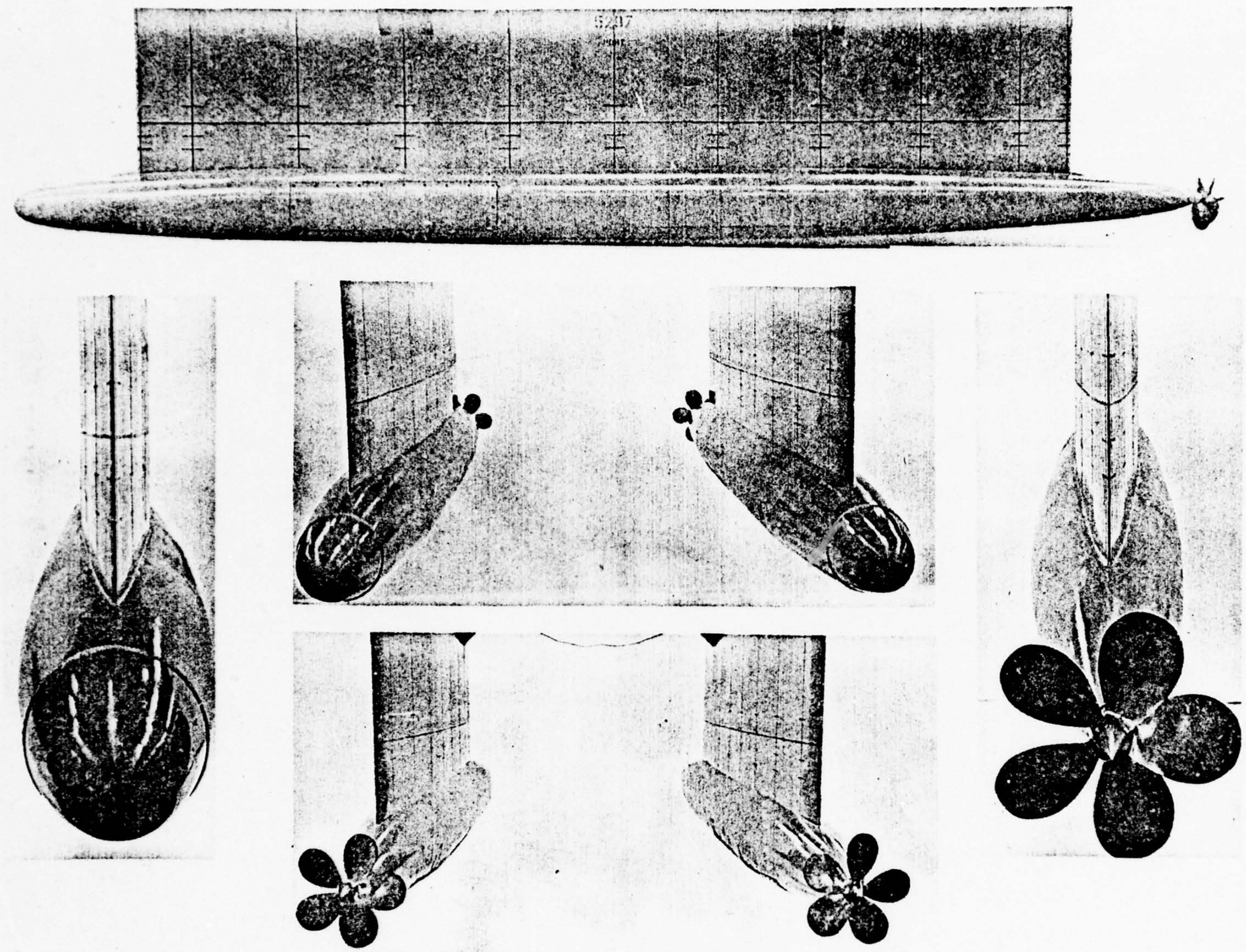


Figure 5 - Fitting-Room Photographs of Model 5287 with Propeller 3217 and 3218

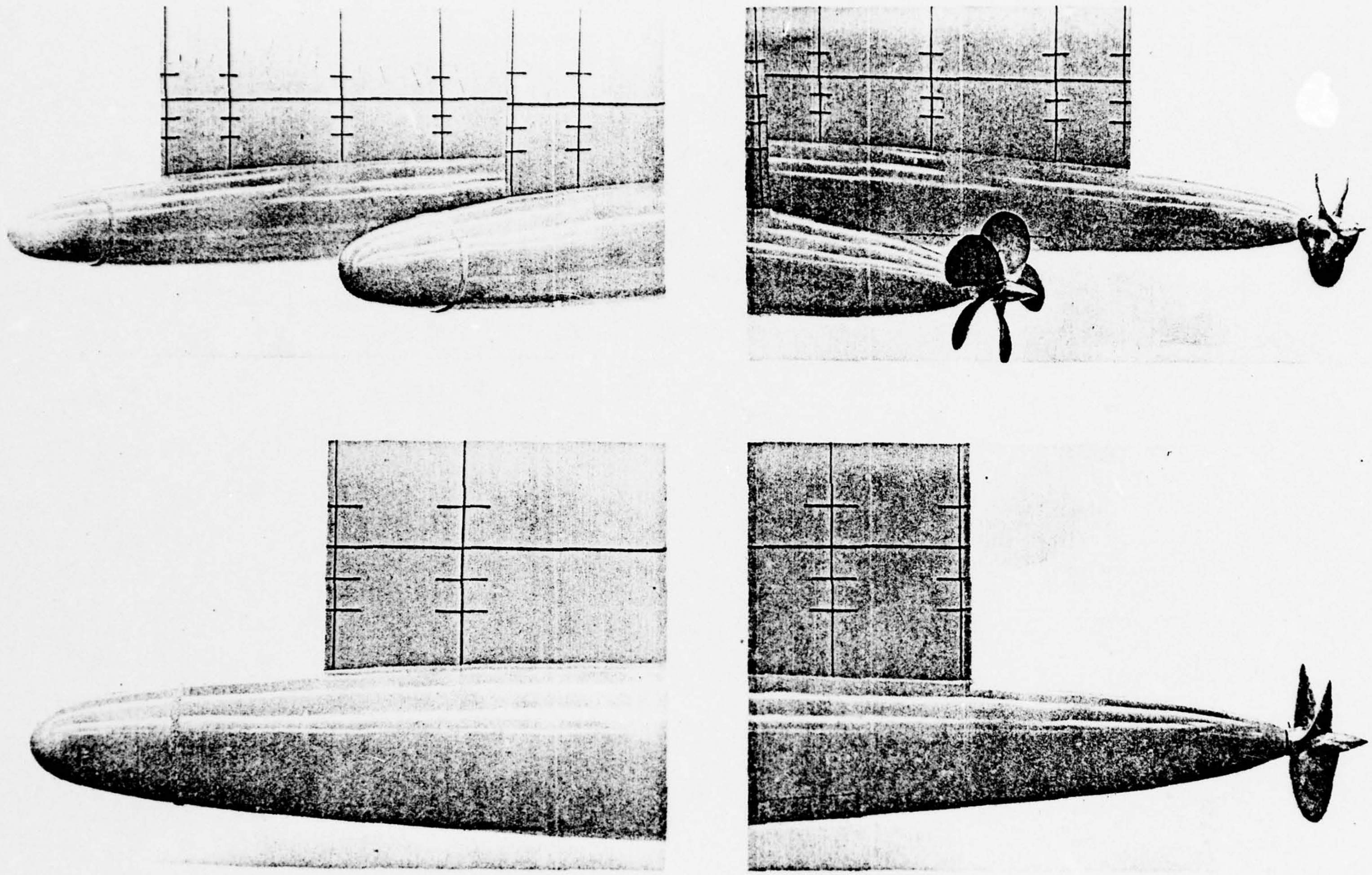


Figure 6 - Fitting-Room Photographs of Model 5287 with Propellers 3217 and 3218

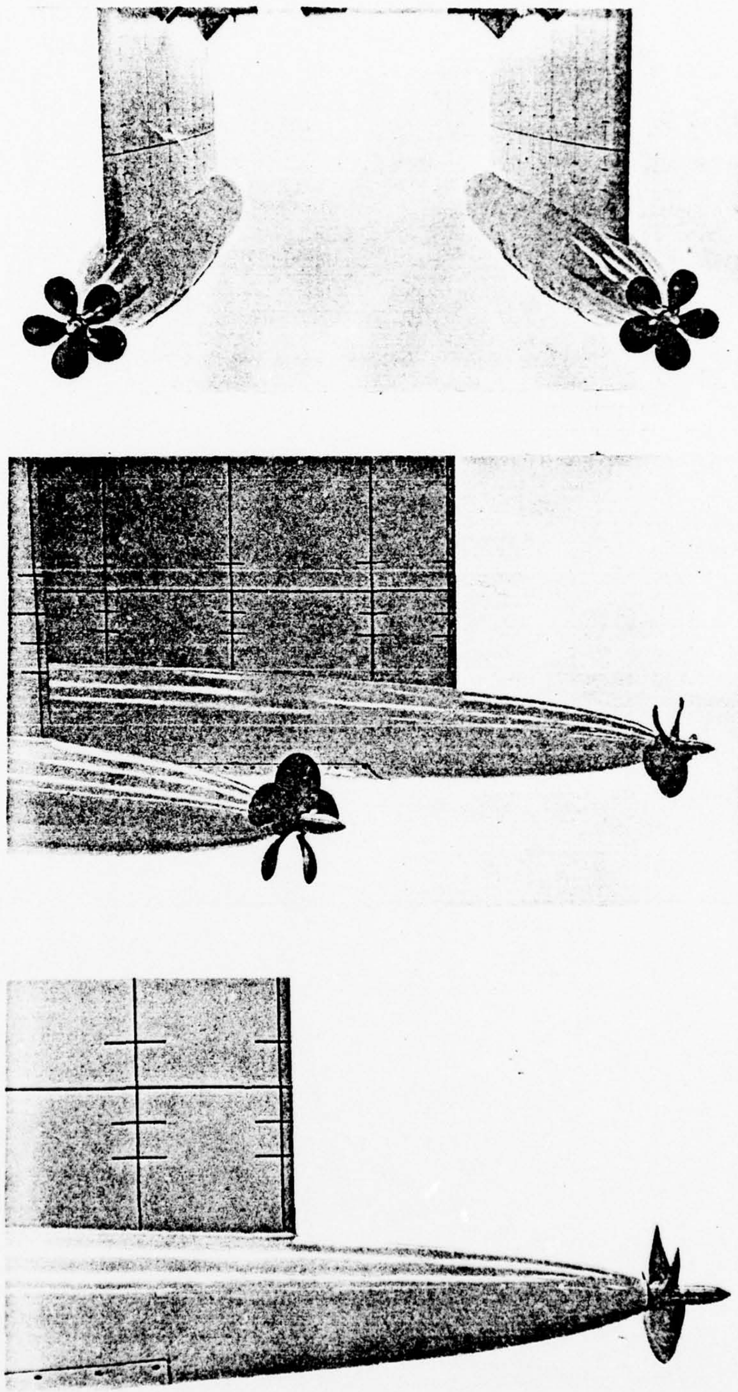


Figure 7 - Fitting-Room Photographs of Model 5287 with .lers 4415 and 4416

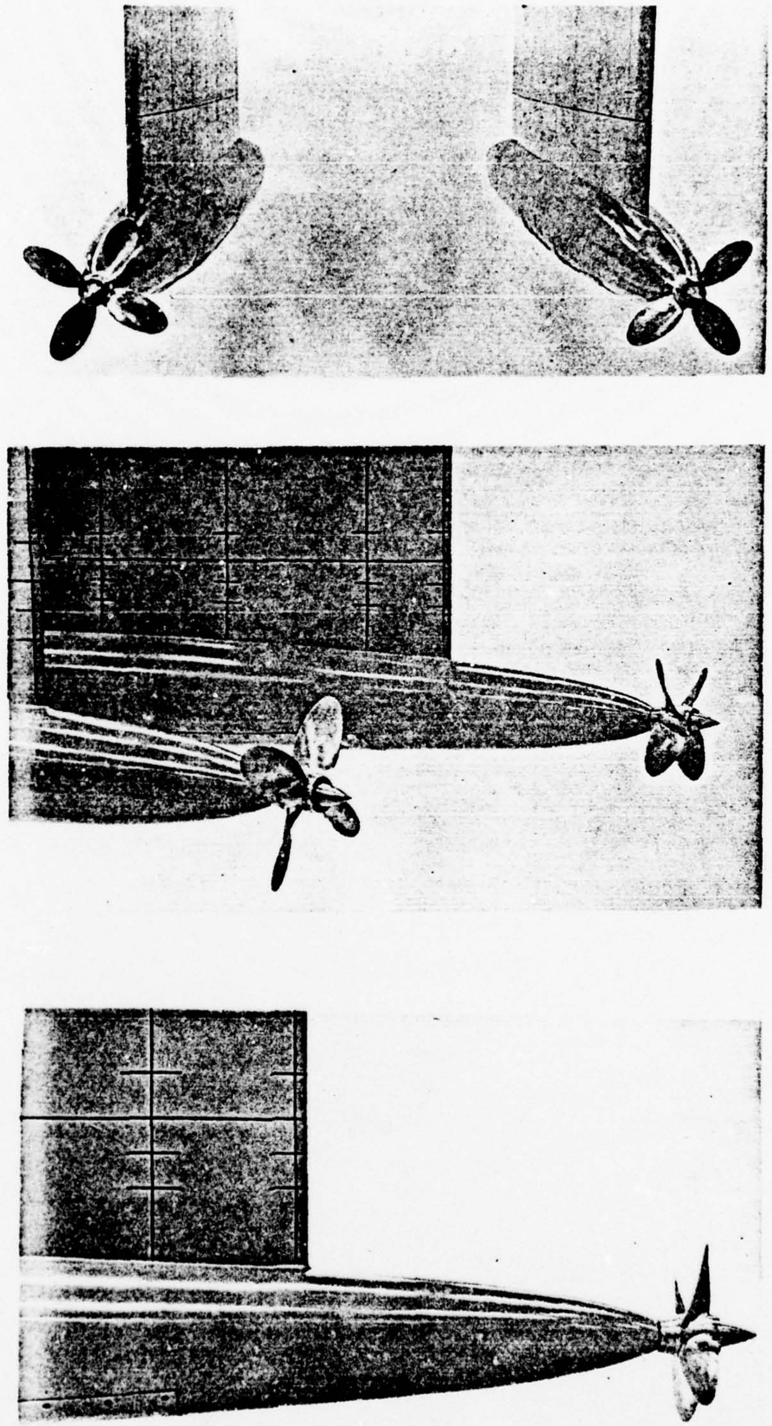


Figure 8 - Fitting-Room Photographs of Model 5287 with Propellers 585 and 586

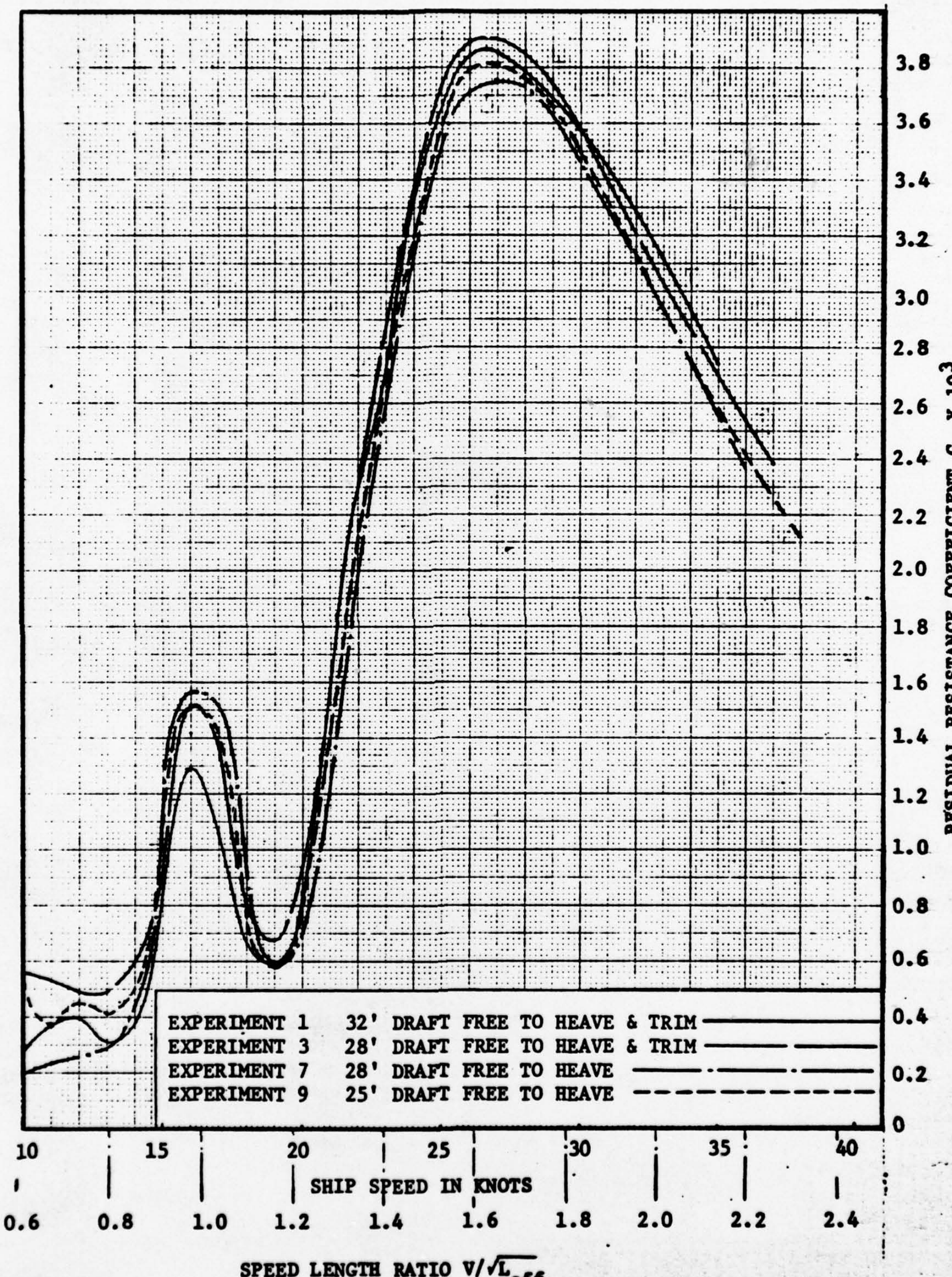


Figure 9 - Residual Resistance Coefficient Comparison for SWATH IV Estimated from Resistance Experiments with Model 5287

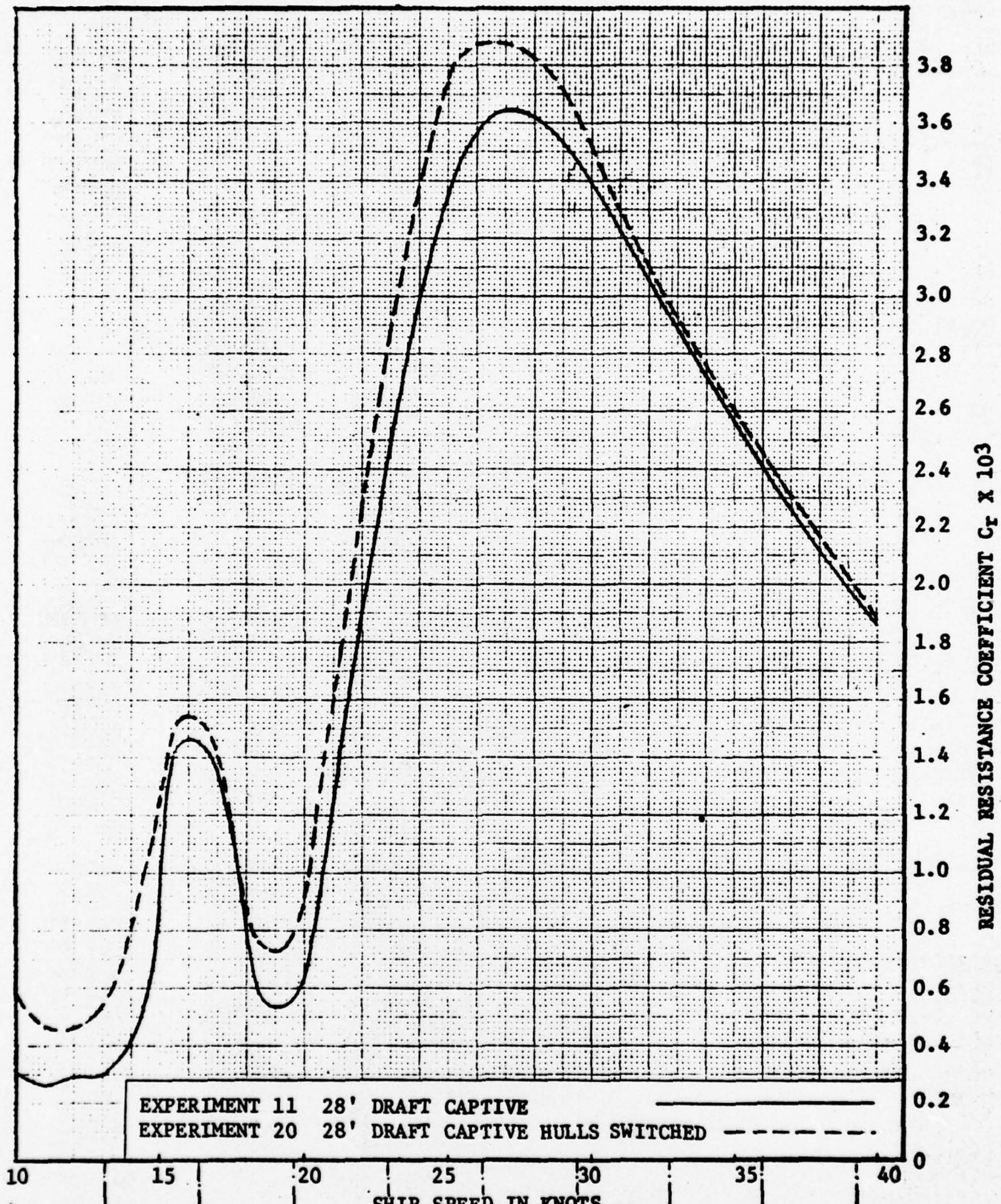


Figure 10 - Residual Resistance Coefficient Comparison for SWATH IV Estimated from Resistance Experiments with Model 5287

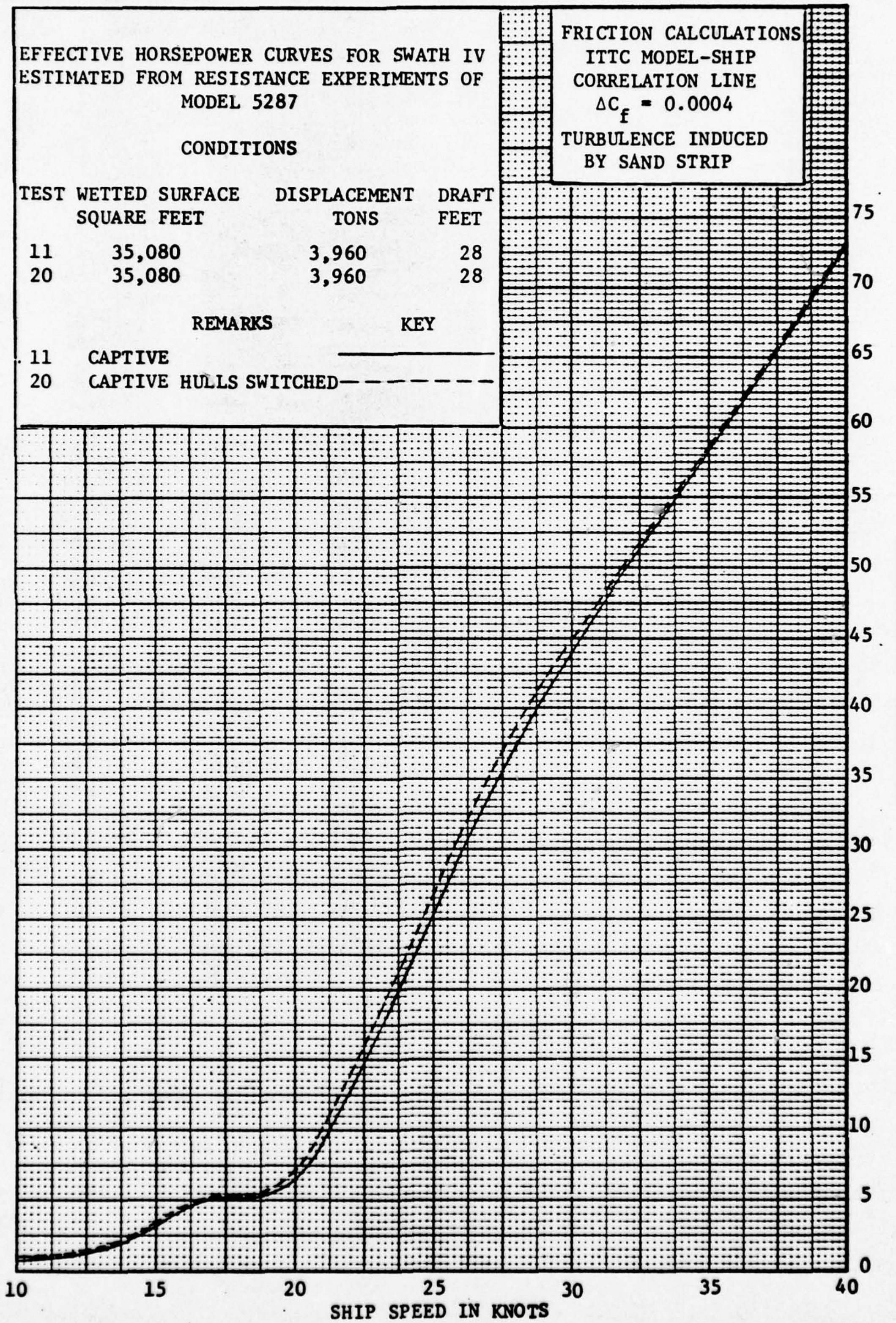

EFFECTIVE HORSEPOWER CURVES FOR SWATH IV
ESTIMATED FROM RESISTANCE EXPERIMENTS OF
MODEL 5287
CONDITIONS
TEST WETTED SURFACE SQUARE FEET DISPLACEMENT TONS DRAFT FEET
11 35,080 3,960 28
20 35,080 3,960 28
REMARKS KEY
11 CAPTIVE
20 CAPTIVE HULLS SWITCHED
FRICTION CALCULATIONS
ITTC MODEL-SHIP
CORRELATION LINE
$\Delta C_f = 0.0004$
TURBULENCE INDUCED
BY SAND STRIP
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75
HORSEPOWER IN THOUSANDS
10 15 20 25 30 35 40
SHIP SPEED IN KNOTS

Figure 11

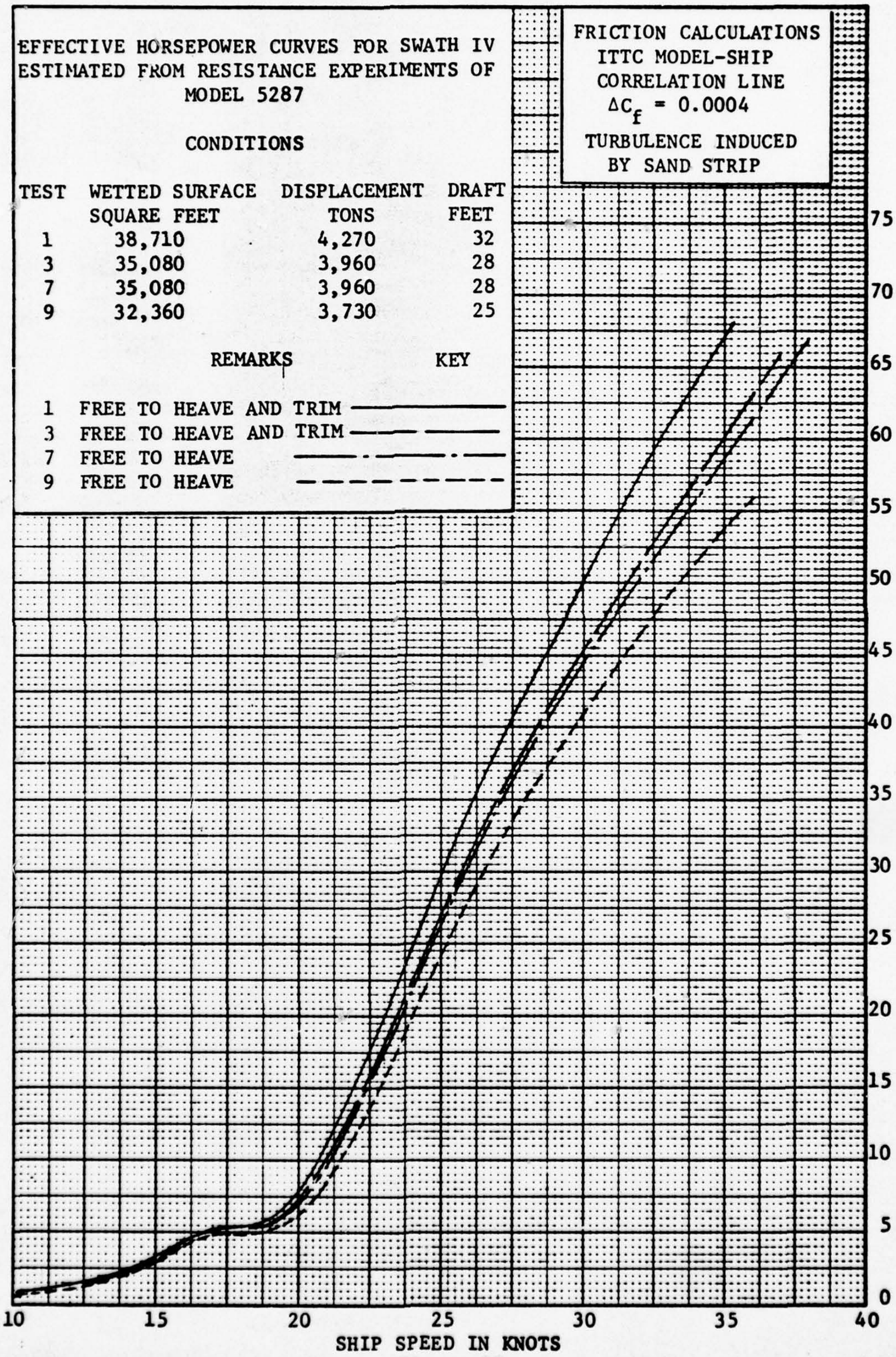

EFFECTIVE HORSEPOWER CURVES FOR SWATH IV
ESTIMATED FROM RESISTANCE EXPERIMENTS OF
MODEL 5287
CONDITIONS
TEST WETTED SURFACE SQUARE FEET DISPLACEMENT TONS DRAFT FEET
1 38,710 4,270 32
3 35,080 3,960 28
7 35,080 3,960 28
9 32,360 3,730 25
REMARKS KEY
1 FREE TO HEAVE AND TRIM
3 FREE TO HEAVE AND TRIM
7 FREE TO HEAVE
9 FREE TO HEAVE
FRICTION CALCULATIONS
ITTC MODEL-SHIP
CORRELATION LINE
ΔC_f = 0.0004
TURBULENCE INDUCED
BY SAND STRIP
HORSEPOWER IN THOUSANDS
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
10
15
20
25
30
35
40
SHIP SPEED IN KNOTS

Figure 12

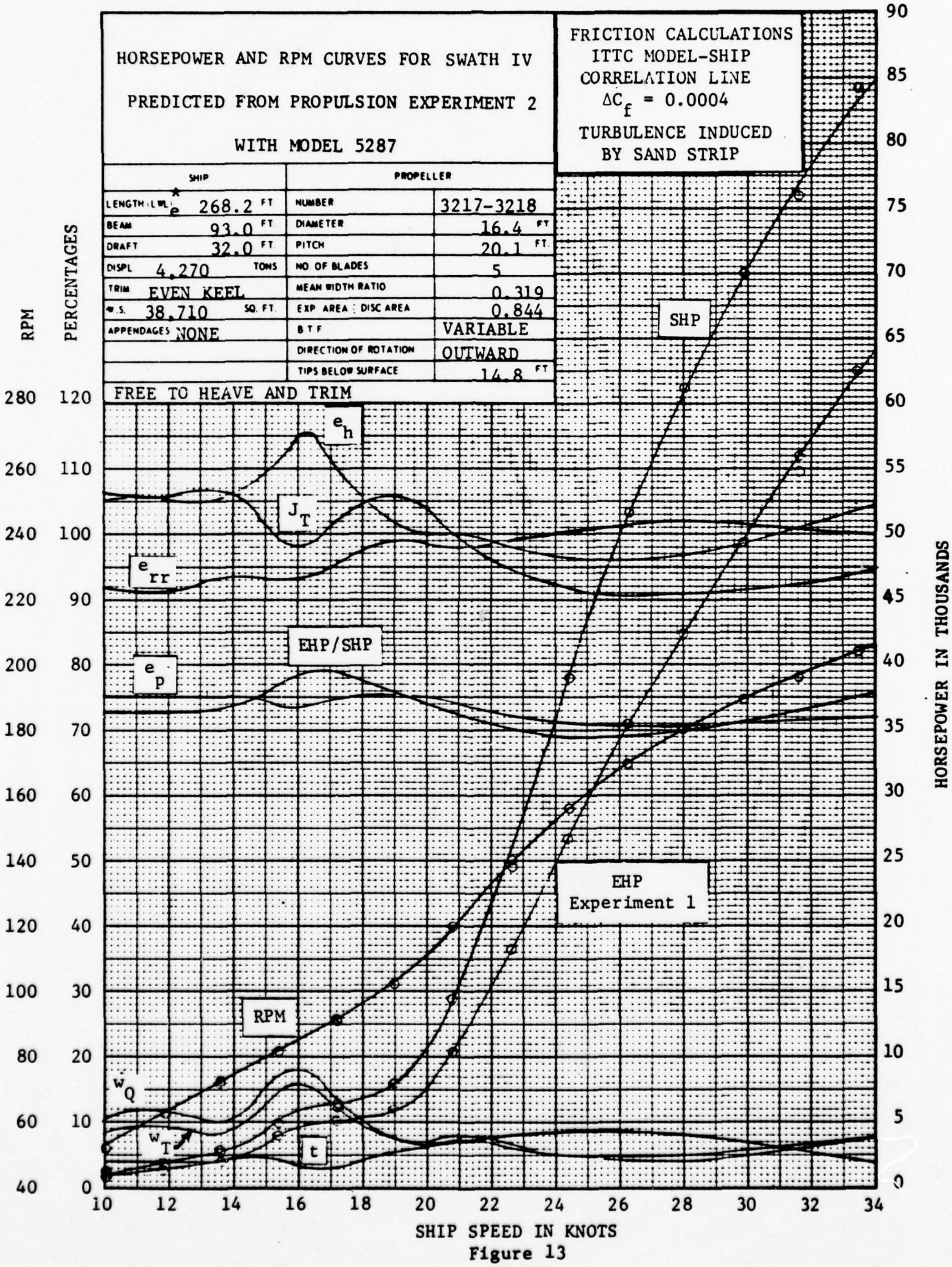

HORSEPOWER AND RPM CURVES FOR SWATH IV
PREDICTED FROM PROPULSION EXPERIMENT 2
WITH MODEL 5287
FRICTION CALCULATIONS
ITTC MODEL-SHIP
CORRELATION LINE
ΔC_f = 0.0004
TURBULENCE INDUCED
BY SAND STRIP
SHIP
PROPELLER
LENGTH (LWL) 268.2 FT
BEAM 93.0 FT
DRAFT 32.0 FT
DISPL 4,270 TONS
TRIM EVEN KEEL
W.S. 38,710 SQ. FT.
APPENDAGES NONE
NUMBER 3217-3218
DIAMETER 16.4 FT
PITCH 20.1 FT
NO OF BLADES 5
MEAN WIDTH RATIO 0.319
EXP AREA : DISC AREA 0.844
BTF VARIABLE
DIRECTION OF ROTATION OUTWARD
TIPS BELOW SURFACE 14.8 FT
FREE TO HEAVE AND TRIM
RPM
PERCENTAGES
HORSEPOWER IN THOUSANDS
SHIP SPEED IN KNOTS
e_h
J_T
e_{rr}
EHP/SHP
e_p
SHP
EHP
Experiment 1
RPM
w_Q
w_T
t

Figure 13

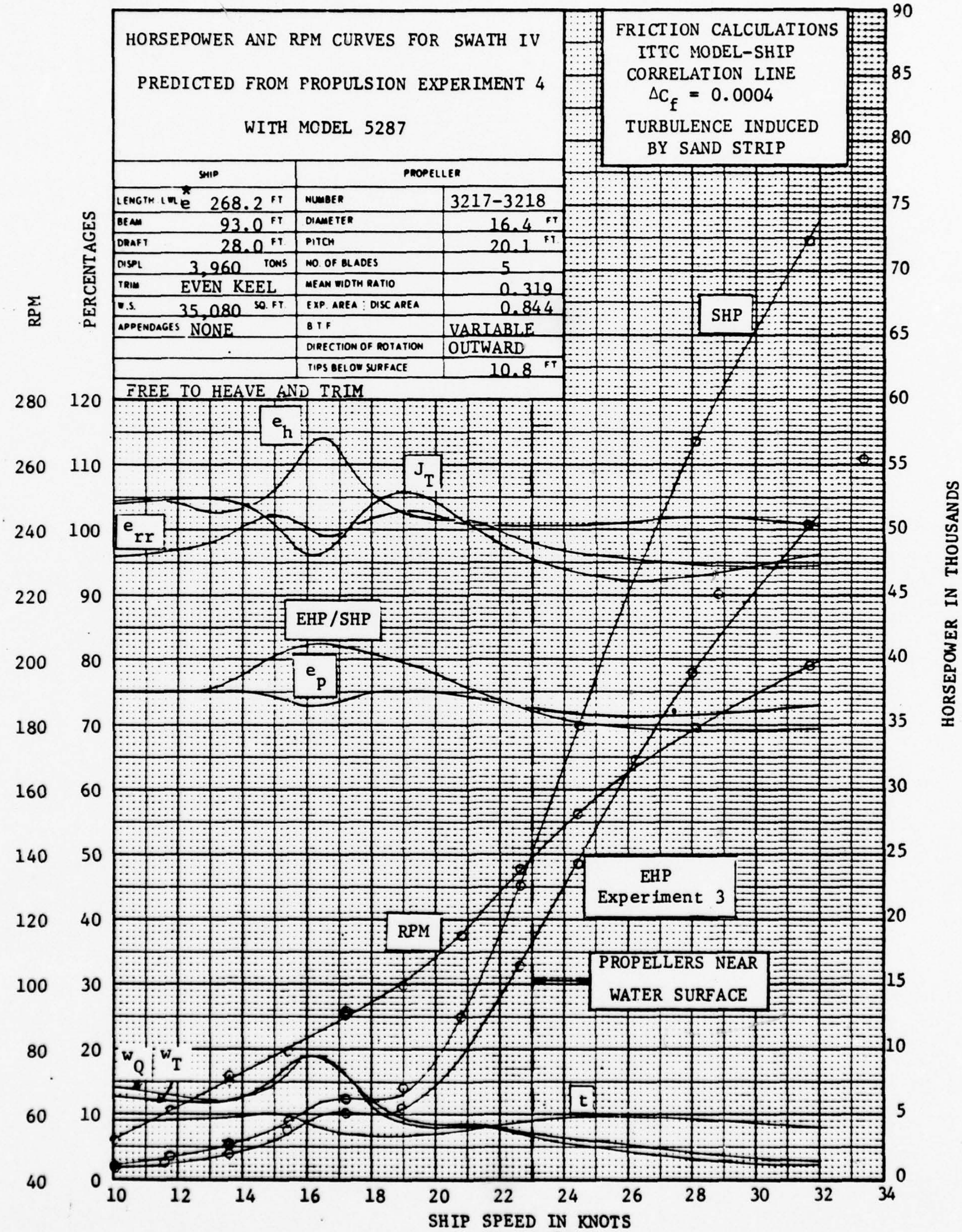
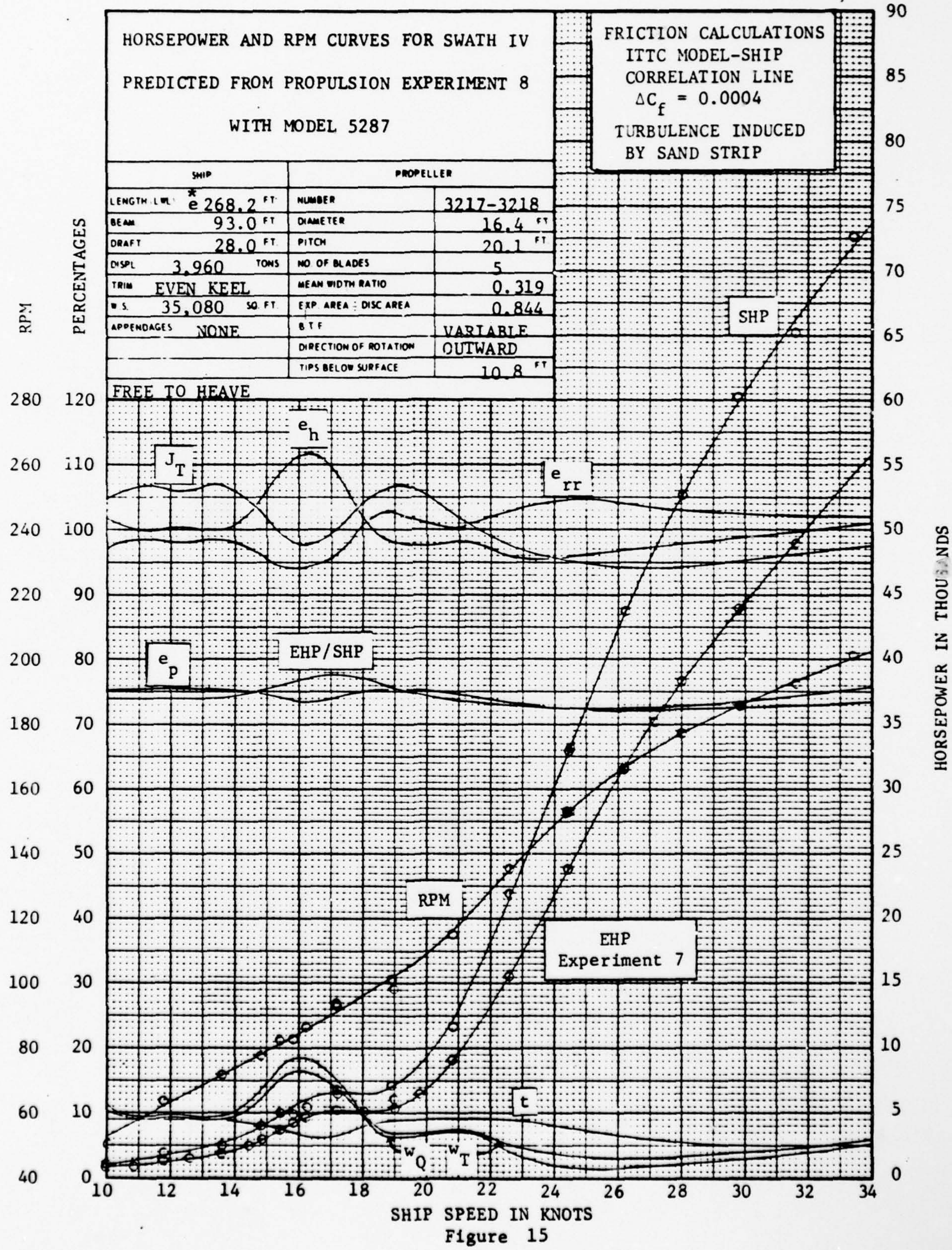
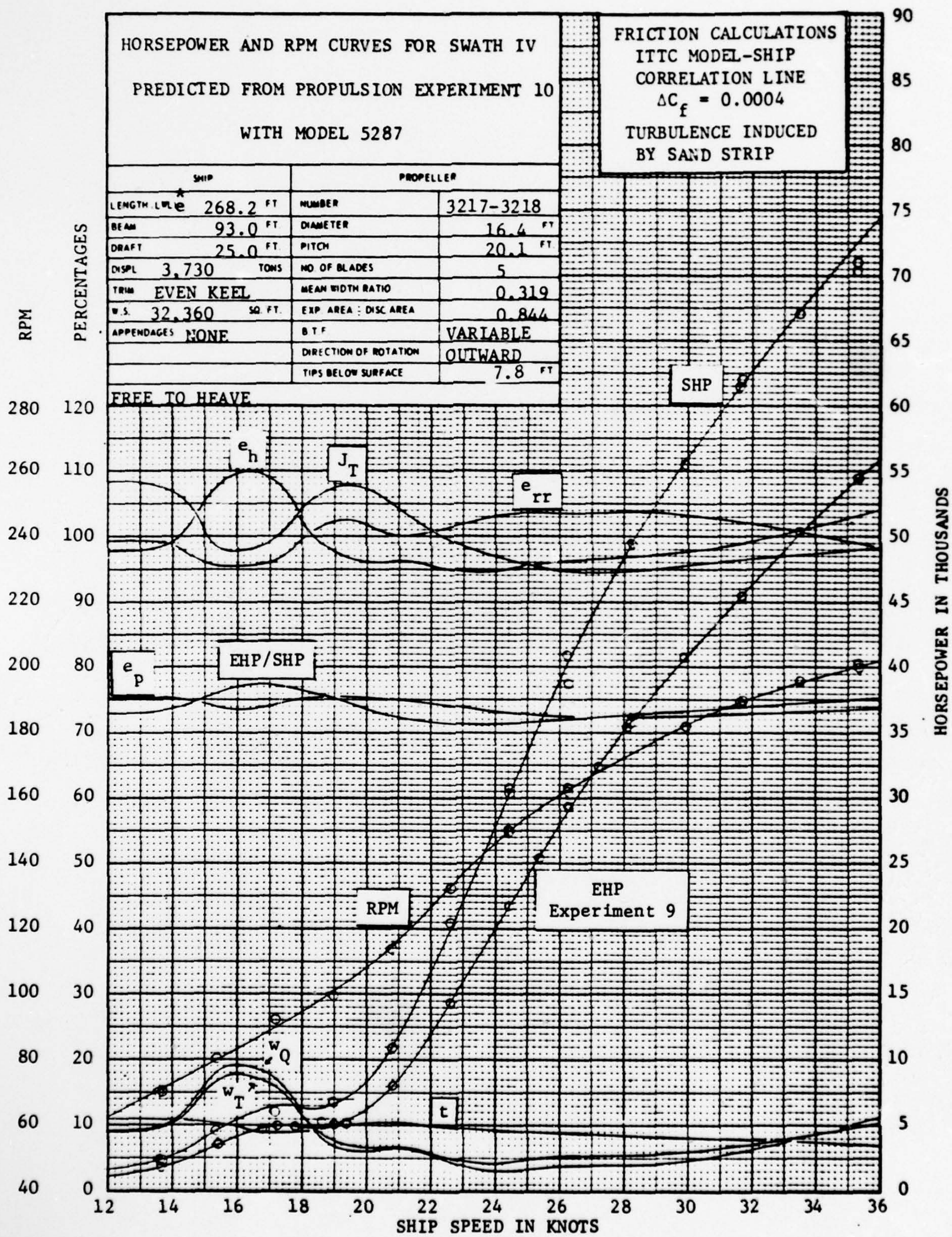

HORSEPOWER AND RPM CURVES FOR SWATH IV
PREDICTED FROM PROPULSION EXPERIMENT 4
WITH MODEL 5287
SHIP
LENGTH LWL 268.2 FT
BEAM 93.0 FT
DRAFT 28.0 FT
DISPL 3,960 TONS
TRIM EVEN KEEL
W.S. 35,080 SQ. FT
APPENDAGES NONE
PROPELLER
NUMBER 3217-3218
DIAMETER 16.4 FT
PITCH 20.1 FT
NO. OF BLADES 5
MEAN WIDTH RATIO 0.319
EXP. AREA : DISC AREA 0.844
BTF VARIABLE
DIRECTION OF ROTATION OUTWARD
TIPS BELOW SURFACE 10.8 FT
FREE TO HEAVE AND TRIM
FRICTION CALCULATIONS
ITTC MODEL-SHIP
CORRELATION LINE
ΔCf = 0.0004
TURBULENCE INDUCED
BY SAND STRIP
RPM
PERCENTAGES
HORSEPOWER IN THOUSANDS
SHIP SPEED IN KNOTS
SHP
eh
JT
err
EHP/SHP
ep
EHP
Experiment 3
RPM
PROPELLERS NEAR
WATER SURFACE
wQ
wT
t

Figure 14



HORSEPOWER AND RPM CURVES FOR SWATH IV
PREDICTED FROM PROPULSION EXPERIMENT 8
WITH MODEL 5287
FRICTION CALCULATIONS
ITTC MODEL-SHIP
CORRELATION LINE
ΔCf = 0.0004
TURBULENCE INDUCED
BY SAND STRIP
SHIP
PROPELLER
LENGTH (LWL) * e 268.2 FT
BEAM 93.0 FT
DRAFT 28.0 FT
DISPL 3,960 TONS
TRIM EVEN KEEL
W.S. 35,080 SQ. FT.
APPENDAGES NONE
NUMBER 3217-3218
DIAMETER 16.4 FT
PITCH 20.1 FT
NO. OF BLADES 5
MEAN WIDTH RATIO 0.319
EXP. AREA : DISC AREA 0.844
B.T.F. VARIABLE
DIRECTION OF ROTATION OUTWARD
TIPS BELOW SURFACE 10.8 FT
FREE TO HEAVE
RPM
PERCENTAGES
HORSEPOWER IN THOUSANDS
SHIP SPEED IN KNOTS
eh
JT
err
ep
EHP/SHP
SHP
RPM
EHP
Experiment 7
t
wQ
wT
280 260 240 220 200 180 160 140 120 100 80 60 40
120 110 100 90 80 70 60 50 40 30 20 10 0
90 85 80 75 70 65 60 55 50 45 40 35 30 25 20 15 10 5 0
10 12 14 16 18 20 22 24 26 28 30 32 34

Figure 15



HORSEPOWER AND RPM CURVES FOR SWATH IV
PREDICTED FROM PROPULSION EXPERIMENT 10
WITH MODEL 5287
FRICTION CALCULATIONS
ITTC MODEL-SHIP
CORRELATION LINE
ΔC_f = 0.0004
TURBULENCE INDUCED
BY SAND STRIP
SHIP
LENGTH LWL 268.2 FT
BEAM 93.0 FT
DRAFT 25.0 FT
DISPL 3,730 TONS
TRIM EVEN KEEL
W.S. 32,360 SQ. FT.
APPENDAGES NONE
PROPELLER
NUMBER 3217-3218
DIAMETER 16.4 FT
PITCH 20.1 FT
NO OF BLADES 5
MEAN WIDTH RATIO 0.319
EXP AREA : DISC AREA 0.844
BTF VARIABLE
DIRECTION OF ROTATION OUTWARD
TIPS BELOW SURFACE 7.8 FT
FREE TO HEAVE
RPM
PERCENTAGES
HORSEPOWER IN THOUSANDS
SHIP SPEED IN KNOTS
SHP
e_h
J_T
e_{rr}
e_p
EHP/SHP
EHP
Experiment 9
RPM
w_Q
w_T
t

Figure 16

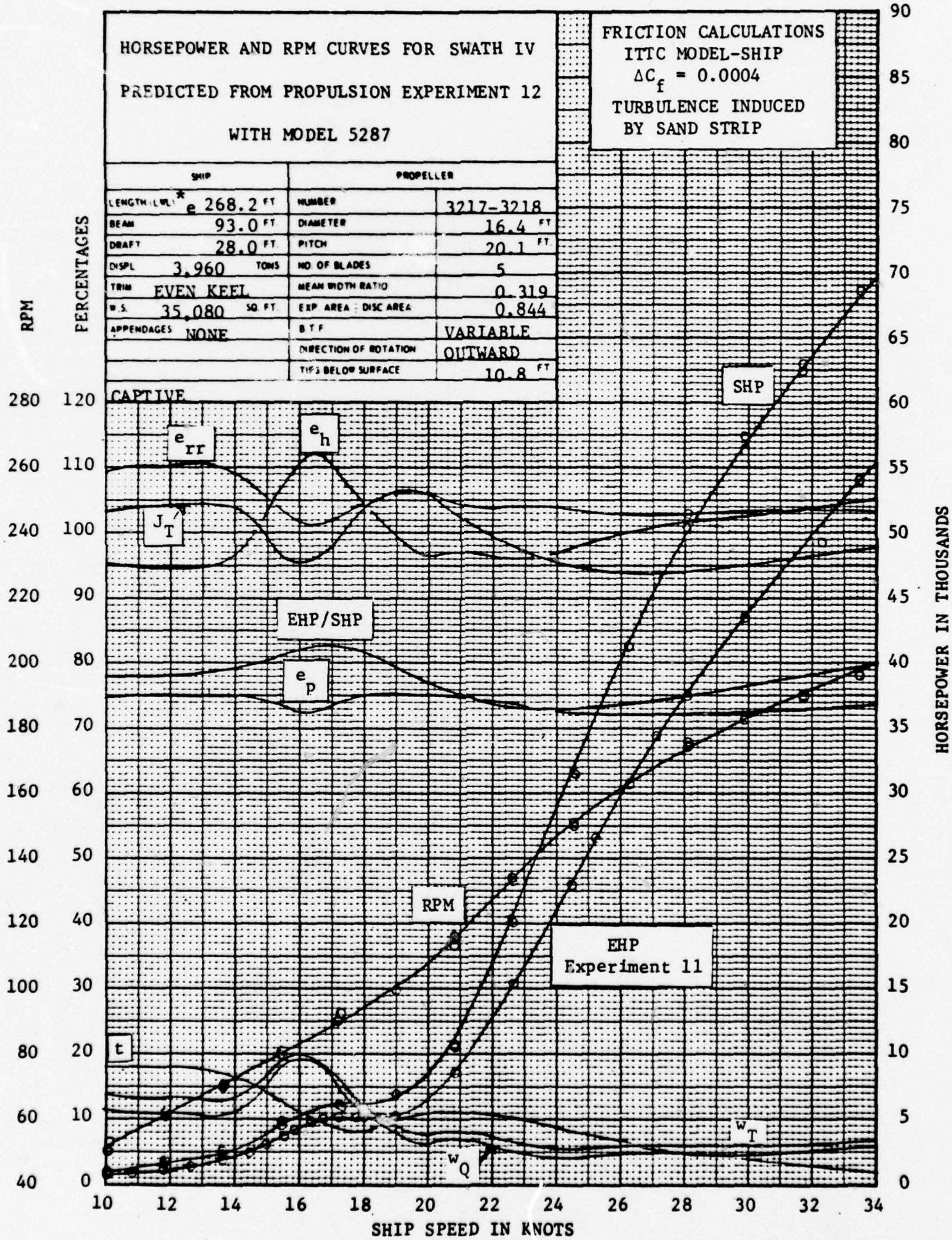

HORSEPOWER AND RPM CURVES FOR SWATH IV
PREDICTED FROM PROPULSION EXPERIMENT 12
WITH MODEL 5287
FRICTION CALCULATIONS
ITTC MODEL-SHIP
ΔC_f = 0.0004
TURBULENCE INDUCED
BY SAND STRIP
SHIP
LENGTH (LWL) * e 268.2 FT
BEAM 93.0 FT
DRAFT 28.0 FT
DISPL 3,960 TONS
TRIM EVEN KEEL
W.S. 35,080 SQ FT
APPENDAGES NONE
PROPELLER
NUMBER 3217-3218
DIAMETER 16.4 FT
PITCH 20.1 FT
NO OF BLADES 5
MEAN WIDTH RATIO 0.319
EXP AREA : DISC AREA 0.844
BTF VARIABLE
DIRECTION OF ROTATION OUTWARD
TIPS BELOW SURFACE 10.8 FT
CAPTIVE
RPM
PERCENTAGES
HORSEPOWER IN THOUSANDS
SHIP SPEED IN KNOTS
e_{rr}
e_h
J_T'
EHP/SHP
e_p
SHP
RPM
EHP
Experiment 11
t
w_T
w_Q
280 260 240 220 200 180 160 140 120 100 80 60 40
120 110 100 90 80 70 60 50 40 30 20 10 0
90 85 80 75 70 65 60 55 50 45 40 35 30 25 20 15 10 5 0
10 12 14 16 18 20 22 24 26 28 30 32 34

Figure 17

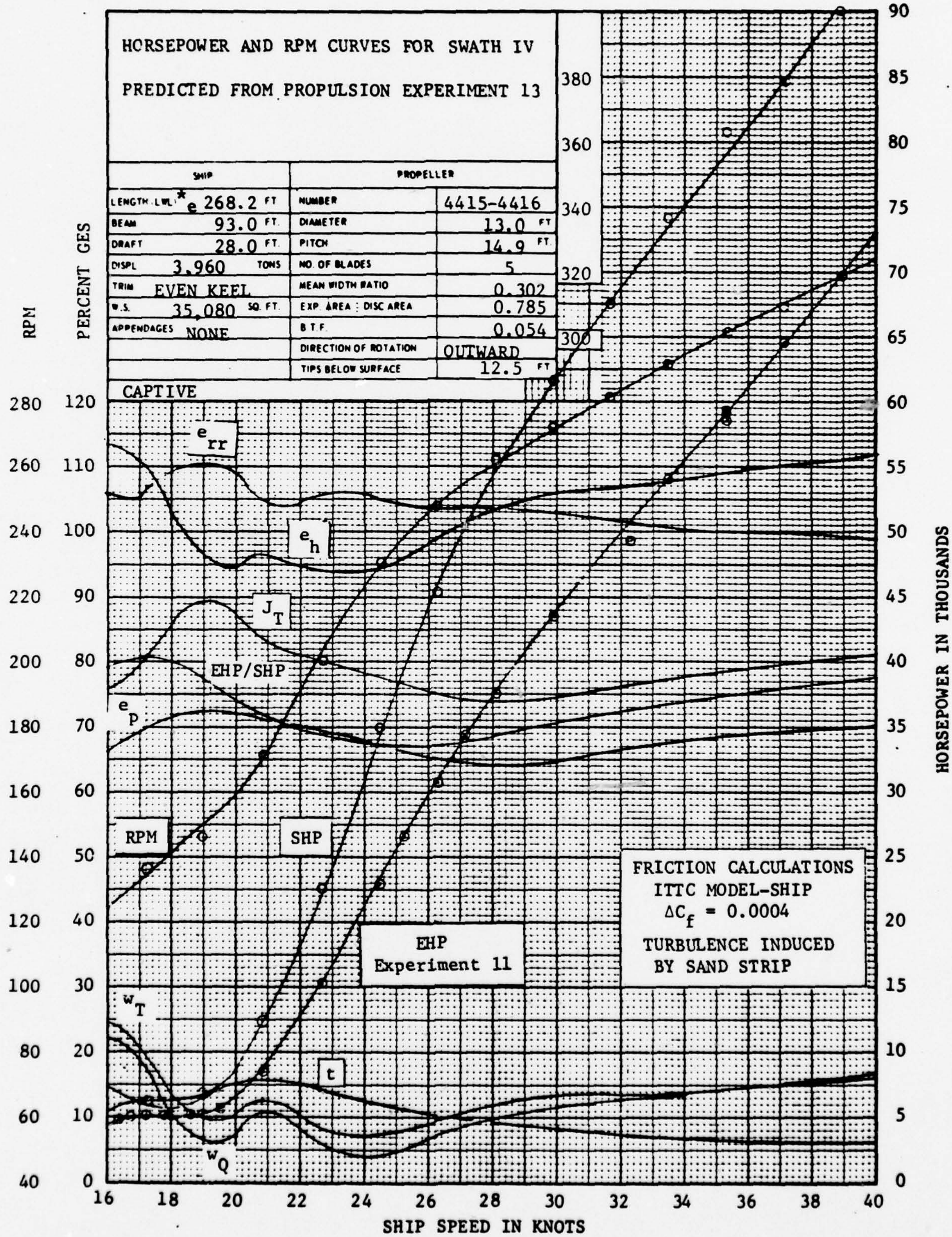

HORSEPOWER AND RPM CURVES FOR SWATH IV
PREDICTED FROM PROPULSION EXPERIMENT 13
SHIP
LENGTH LWL *e 268.2 FT
BEAM 93.0 FT
DRAFT 28.0 FT
DISPL 3,960 TONS
TRIM EVEN KEEL
W.S. 35,080 SQ. FT.
APPENDAGES NONE
PROPELLER
NUMBER 4415-4416
DIAMETER 13.0 FT
PITCH 14.9 FT
NO. OF BLADES 5
MEAN WIDTH RATIO 0.302
EXP. AREA : DISC AREA 0.785
B.T.F. 0.054
DIRECTION OF ROTATION OUTWARD
TIPS BELOW SURFACE 12.5 FT
CAPTIVE
RPM
PERCENT GES
HORSEPOWER IN THOUSANDS
SHIP SPEED IN KNOTS
e_{rr}
e_h
J_T
EHP/SHP
e_p
RPM
SHP
EHP
Experiment 11
w_T
t
w_Q
FRICTION CALCULATIONS
ITTC MODEL-SHIP
ΔC_f = 0.0004
TURBULENCE INDUCED
BY SAND STRIP

Figure 18

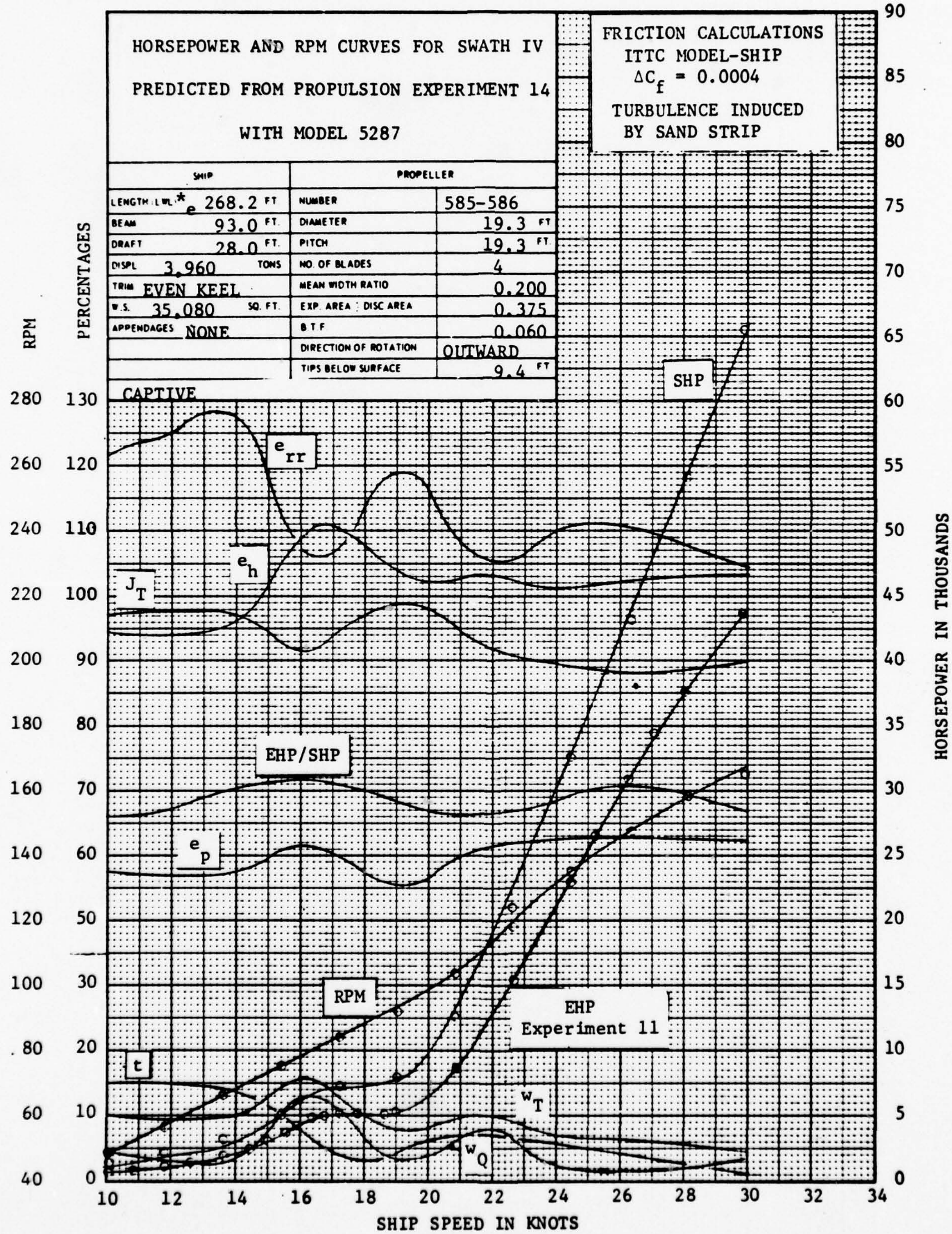

HORSEPOWER AND RPM CURVES FOR SWATH IV
PREDICTED FROM PROPULSION EXPERIMENT 14
WITH MODEL 5287
FRICTION CALCULATIONS
ITTC MODEL-SHIP
ΔC_f = 0.0004
TURBULENCE INDUCED
BY SAND STRIP
SHIP
PROPELLER
LENGTH LWL *e 268.2 FT
BEAM 93.0 FT
DRAFT 28.0 FT
DISPL 3,960 TONS
TRIM EVEN KEEL
W.S. 35,080 SQ. FT.
APPENDAGES NONE
NUMBER 585-586
DIAMETER 19.3 FT
PITCH 19.3 FT
NO. OF BLADES 4
MEAN WIDTH RATIO 0.200
EXP. AREA : DISC AREA 0.375
B.T.F 0.060
DIRECTION OF ROTATION OUTWARD
TIPS BELOW SURFACE 9.4 FT
CAPTIVE
RPM
PERCENTAGES
HORSEPOWER IN THOUSANDS
SHP
e_rr
e_h
J_T
EHP/SHP
e_p
RPM
EHP
Experiment 11
t
w_T
w_Q
SHIP SPEED IN KNOTS

Figure 19

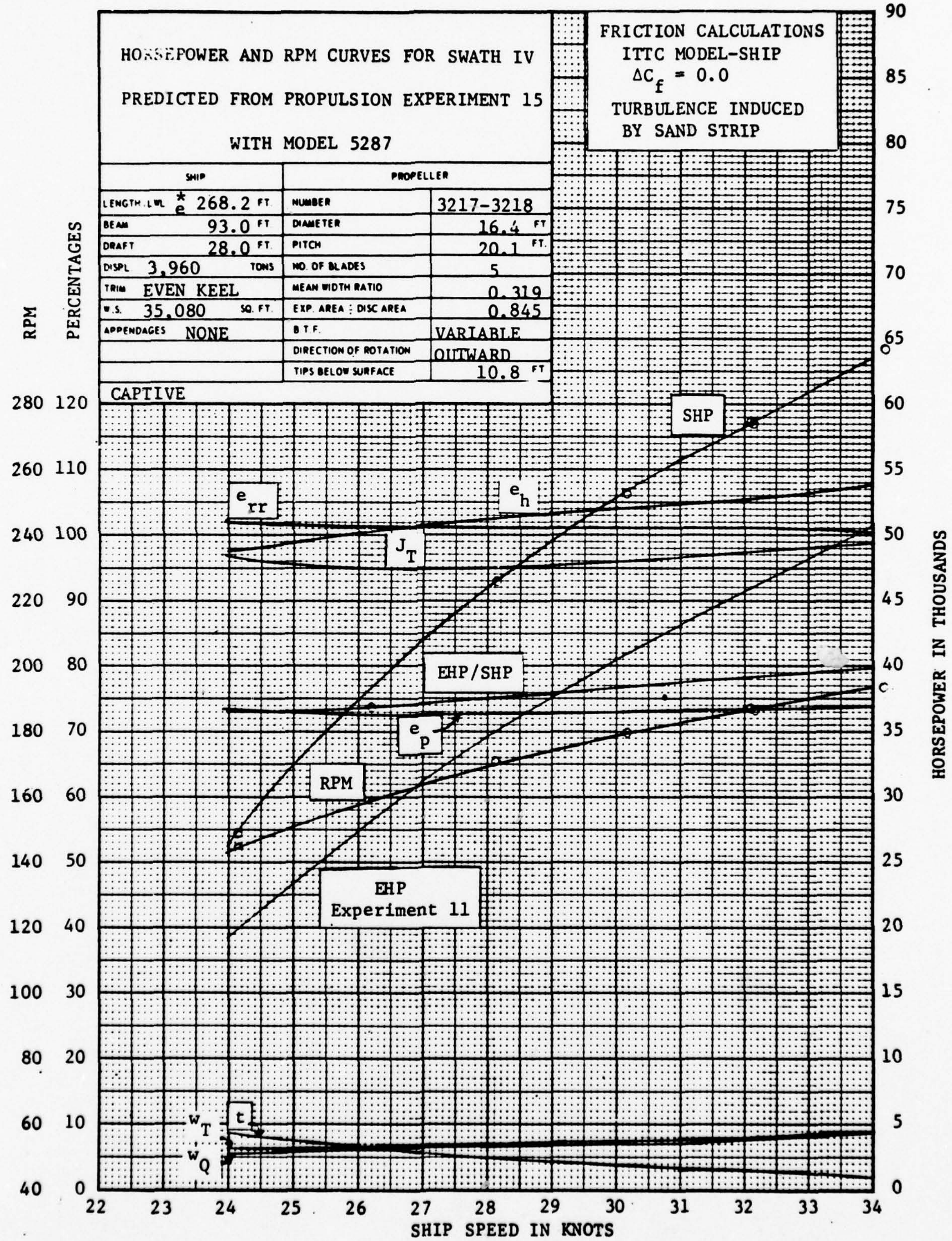
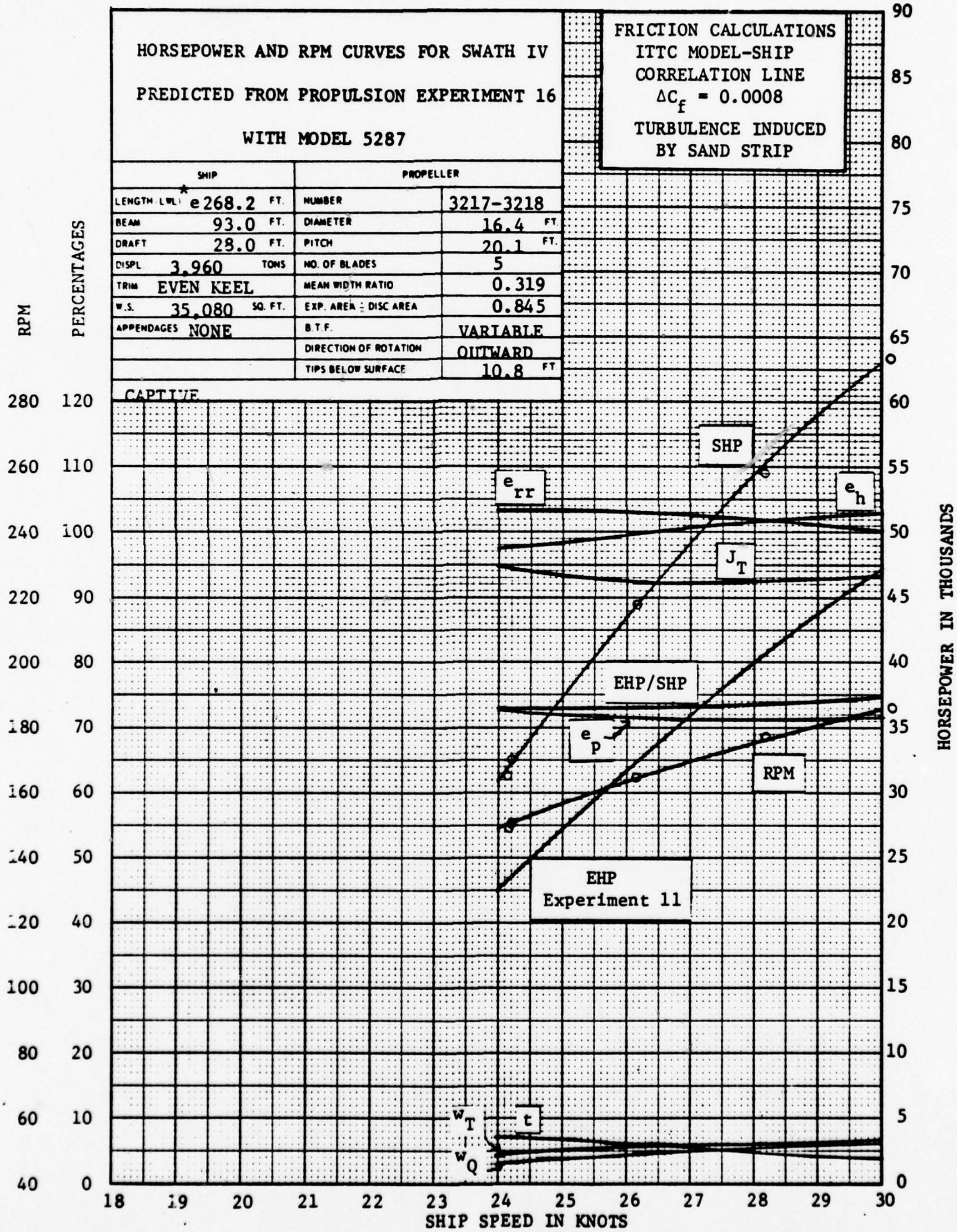

HORSEPOWER AND RPM CURVES FOR SWATH IV
PREDICTED FROM PROPULSION EXPERIMENT 15
WITH MODEL 5287
FRICTION CALCULATIONS
ITTC MODEL-SHIP
$\Delta C_f = 0.0$
TURBULENCE INDUCED
BY SAND STRIP
SHIP
PROPELLER
LENGTH, LWL * 268.2 FT
BEAM 93.0 FT
DRAFT 28.0 FT
DISPL 3,960 TONS
TRIM EVEN KEEL
W.S. 35,080 SQ. FT.
APPENDAGES NONE
NUMBER 3217-3218
DIAMETER 16.4 FT
PITCH 20.1 FT.
NO. OF BLADES 5
MEAN WIDTH RATIO 0.319
EXP. AREA ÷ DISC AREA 0.845
B.T.F. VARIABLE
DIRECTION OF ROTATION OUTWARD
TIPS BELOW SURFACE 10.8 FT
CAPTIVE
SHP
e_{rr}
e_h
J_T
EHP/SHP
e_p
RPM
EHP
Experiment 11
w_T
t
w_Q
RPM
PERCENTAGES
HORSEPOWER IN THOUSANDS
SHIP SPEED IN KNOTS

Figure 20



HORSEPOWER AND RPM CURVES FOR SWATH IV
PREDICTED FROM PROPULSION EXPERIMENT 16
WITH MODEL 5287
FRICTION CALCULATIONS
ITTC MODEL-SHIP
CORRELATION LINE
ΔC_f = 0.0008
TURBULENCE INDUCED
BY SAND STRIP
SHIP
LENGTH (LWL) * e 268.2 FT.
BEAM 93.0 FT.
DRAFT 28.0 FT.
DISPL. 3,960 TONS
TRIM EVEN KEEL
W.S. 35,080 SQ. FT.
APPENDAGES NONE
CAPTIVE
PROPELLER
NUMBER 3217-3218
DIAMETER 16.4 FT.
PITCH 20.1 FT.
NO. OF BLADES 5
MEAN WIDTH RATIO 0.319
EXP. AREA ÷ DISC AREA 0.845
B.T.F. VARIABLE
DIRECTION OF ROTATION OUTWARD
TIPS BELOW SURFACE 10.8 FT
RPM
PERCENTAGES
HORSEPOWER IN THOUSANDS
SHP
e_{rr}
e_h
J_T
EHP/SHP
e_p
RPM
EHP
Experiment 11
w_T
t
w_Q
SHIP SPEED IN KNOTS

Figure 21

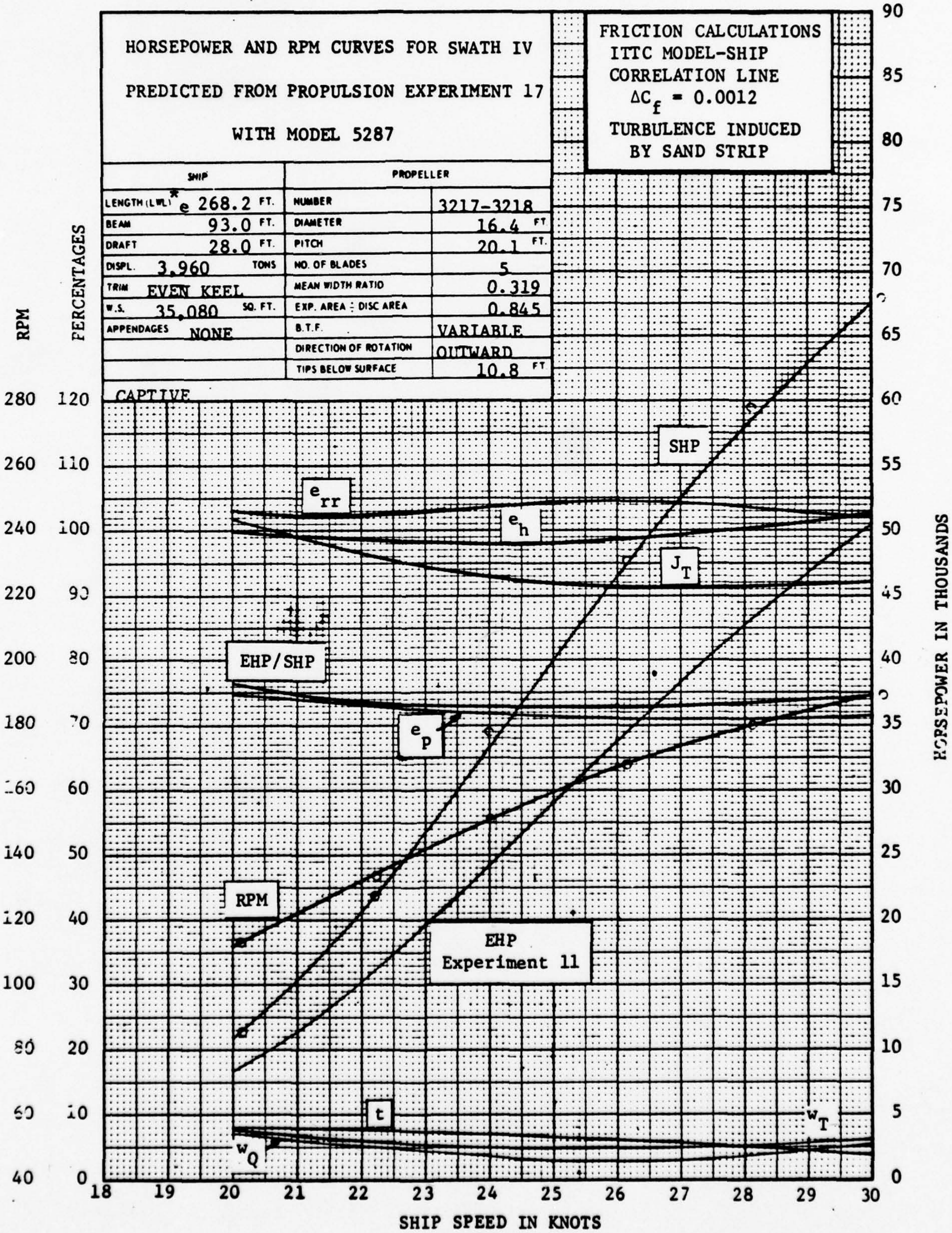

HORSEPOWER AND RPM CURVES FOR SWATH IV
PREDICTED FROM PROPULSION EXPERIMENT 17
WITH MODEL 5287
FRICTION CALCULATIONS
ITTC MODEL-SHIP
CORRELATION LINE
ΔC_f = 0.0012
TURBULENCE INDUCED
BY SAND STRIP
SHIP
LENGTH (LWL)* e 268.2 FT.
BEAM 93.0 FT.
DRAFT 28.0 FT.
DISPL. 3,960 TONS
TRIM EVEN KEEL
W.S. 35,080 SQ. FT.
APPENDAGES NONE
PROPELLER
NUMBER 3217-3218
DIAMETER 16.4 FT
PITCH 20.1 FT.
NO. OF BLADES 5
MEAN WIDTH RATIO 0.319
EXP. AREA ÷ DISC AREA 0.845
B.T.F. VARIABLE
DIRECTION OF ROTATION OUTWARD
TIPS BELOW SURFACE 10.8 FT
CAPTIVE
RPM
PERCENTAGES
HORSEPOWER IN THOUSANDS
SHP
e_rr
e_h
J_T
EHP/SHP
e_p
RPM
EHP
Experiment 11
t
w_T
w_Q
SHIP SPEED IN KNOTS

Figure 22

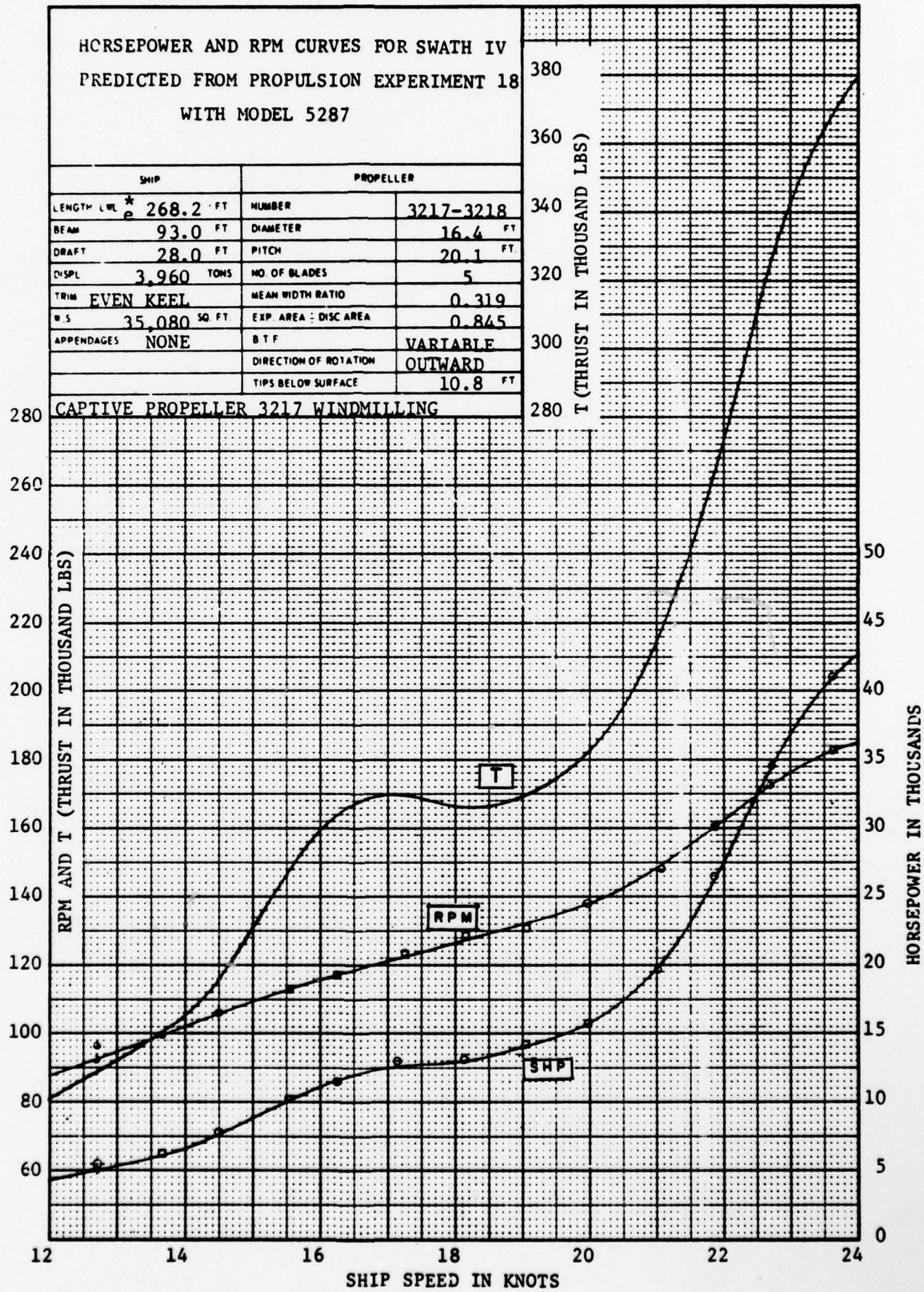

HORSEPOWER AND RPM CURVES FOR SWATH IV
PREDICTED FROM PROPULSION EXPERIMENT 18
WITH MODEL 5287
SHIP
LENGTH LWL * 268.2 FT
BEAM 93.0 FT
DRAFT 28.0 FT
DISPL 3,960 TONS
TRIM EVEN KEEL
W.S 35,080 SQ FT
APPENDAGES NONE
PROPELLER
NUMBER 3217-3218
DIAMETER 16.4 FT
PITCH 20.1 FT
NO. OF BLADES 5
MEAN WIDTH RATIO 0.319
EXP. AREA ÷ DISC AREA 0.845
BTF VARIABLE
DIRECTION OF ROTATION OUTWARD
TIPS BELOW SURFACE 10.8 FT
CAPTIVE PROPELLER 3217 WINDMILLING
T (THRUST IN THOUSAND LBS)
RPM AND T (THRUST IN THOUSAND LBS)
HORSEPOWER IN THOUSANDS
T
RPM
SHP
SHIP SPEED IN KNOTS

Figure 23

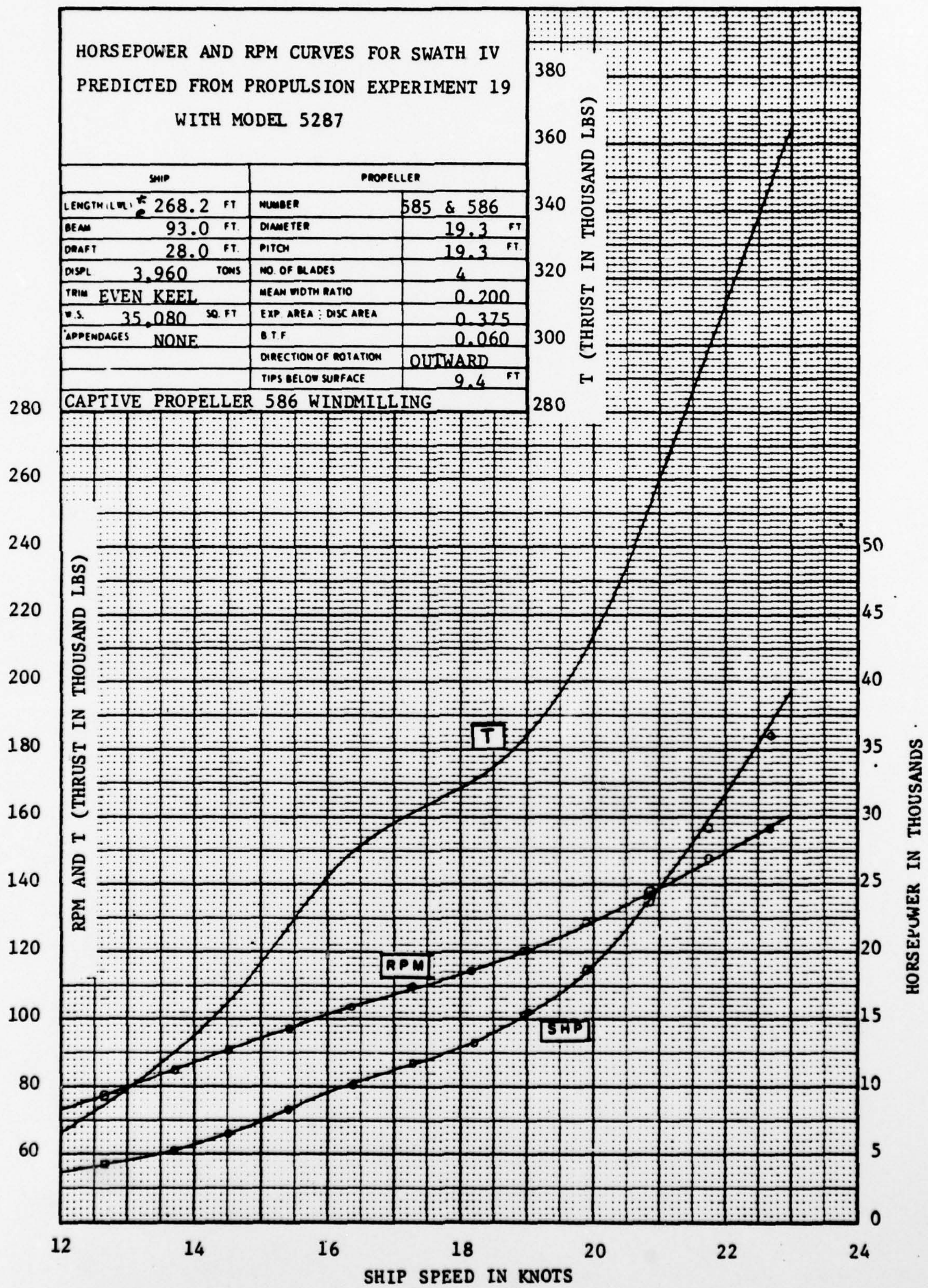

HORSEPOWER AND RPM CURVES FOR SWATH IV
PREDICTED FROM PROPULSION EXPERIMENT 19
WITH MODEL 5287
SHIP
LENGTH (LWL) 268.2 FT
BEAM 93.0 FT
DRAFT 28.0 FT
DISPL 3,960 TONS
TRIM EVEN KEEL
W.S. 35,080 SQ. FT
APPENDAGES NONE
PROPELLER
NUMBER 585 & 586
DIAMETER 19.3 FT
PITCH 19.3 FT
NO. OF BLADES 4
MEAN WIDTH RATIO 0.200
EXP. AREA : DISC AREA 0.375
B.T.F 0.060
DIRECTION OF ROTATION OUTWARD
TIPS BELOW SURFACE 9.4 FT
CAPTIVE PROPELLER 586 WINDMILLING
T (THRUST IN THOUSAND LBS)
RPM AND T (THRUST IN THOUSAND LBS)
HORSEPOWER IN THOUSANDS
T
RPM
SHP
SHIP SPEED IN KNOTS

Figure 24

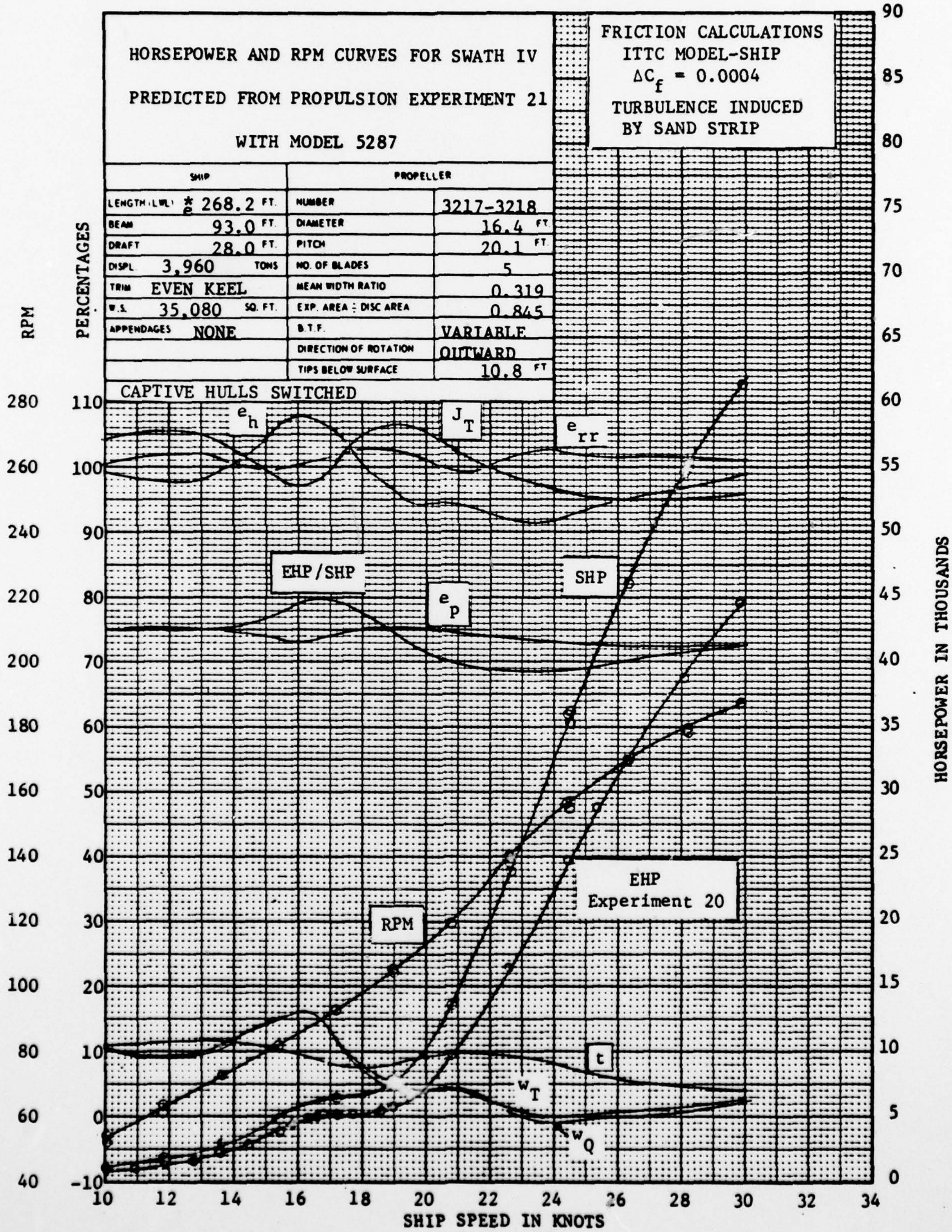

HORSEPOWER AND RPM CURVES FOR SWATH IV
PREDICTED FROM PROPULSION EXPERIMENT 21
WITH MODEL 5287
FRICTION CALCULATIONS
ITTC MODEL-SHIP
ΔC_f = 0.0004
TURBULENCE INDUCED
BY SAND STRIP
SHIP
LENGTH (LWL) * 268.2 FT.
BEAM 93.0 FT.
DRAFT 28.0 FT.
DISPL. 3,960 TONS
TRIM EVEN KEEL
W.S. 35,080 SQ. FT.
APPENDAGES NONE
PROPELLER
NUMBER 3217-3218
DIAMETER 16.4 FT.
PITCH 20.1 FT.
NO. OF BLADES 5
MEAN WIDTH RATIO 0.319
EXP. AREA ÷ DISC AREA 0.845
B.T.F. VARIABLE
DIRECTION OF ROTATION OUTWARD
TIPS BELOW SURFACE 10.8 FT
CAPTIVE HULLS SWITCHED
e_h
J_T
e_{rr}
EHP/SHP
e_p
SHP
EHP Experiment 20
RPM
t
w_T
w_Q
RPM
PERCENTAGES
HORSEPOWER IN THOUSANDS
SHIP SPEED IN KNOTS

Figure 25

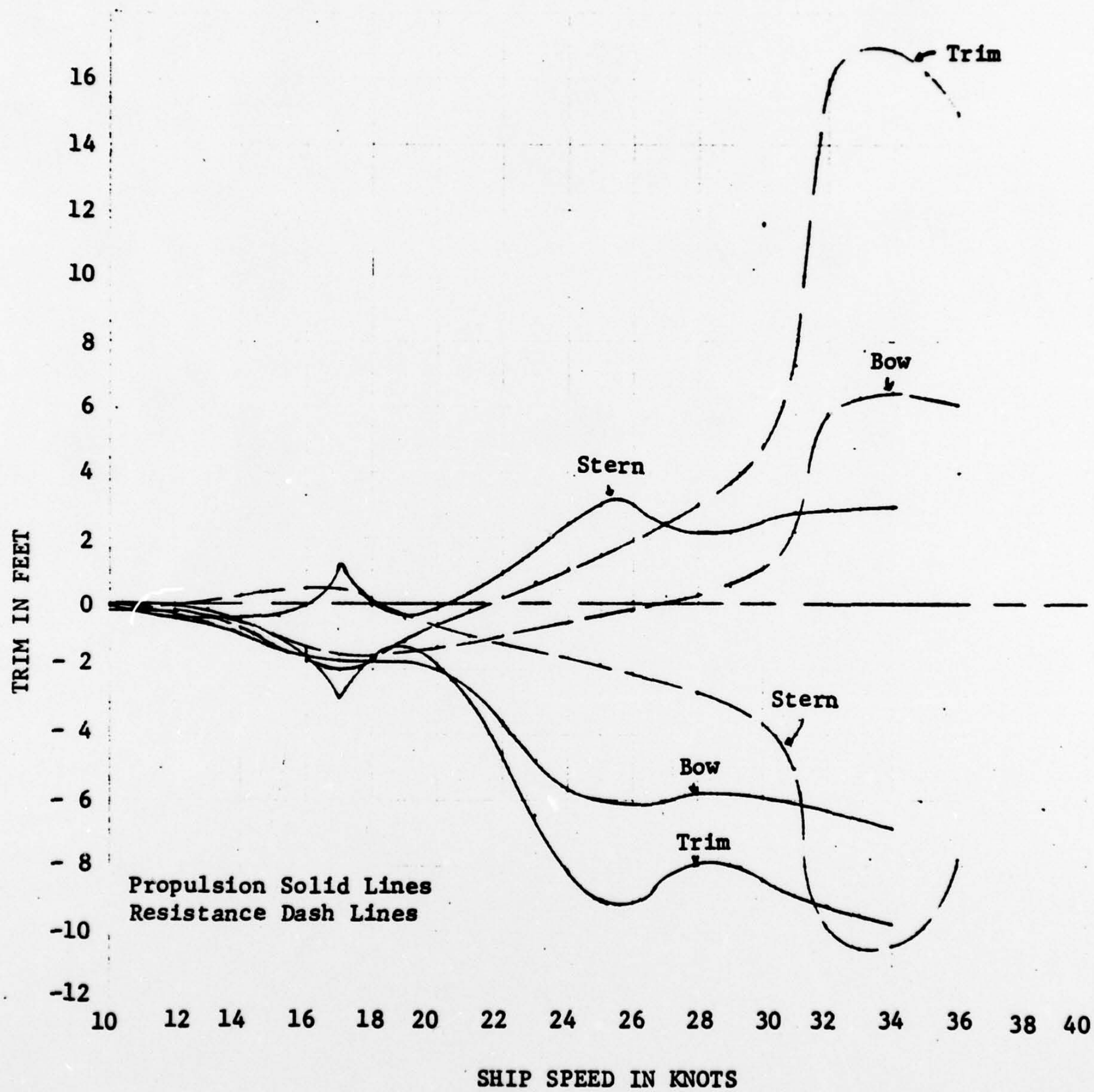


Figure 26 - Change of Level and Trim Characteristic Curves for SWATH IV Estimated from Resistance and Propulsion Experiments with Model 5287 at a 32-foot Draft (Free to Heave and Trim)

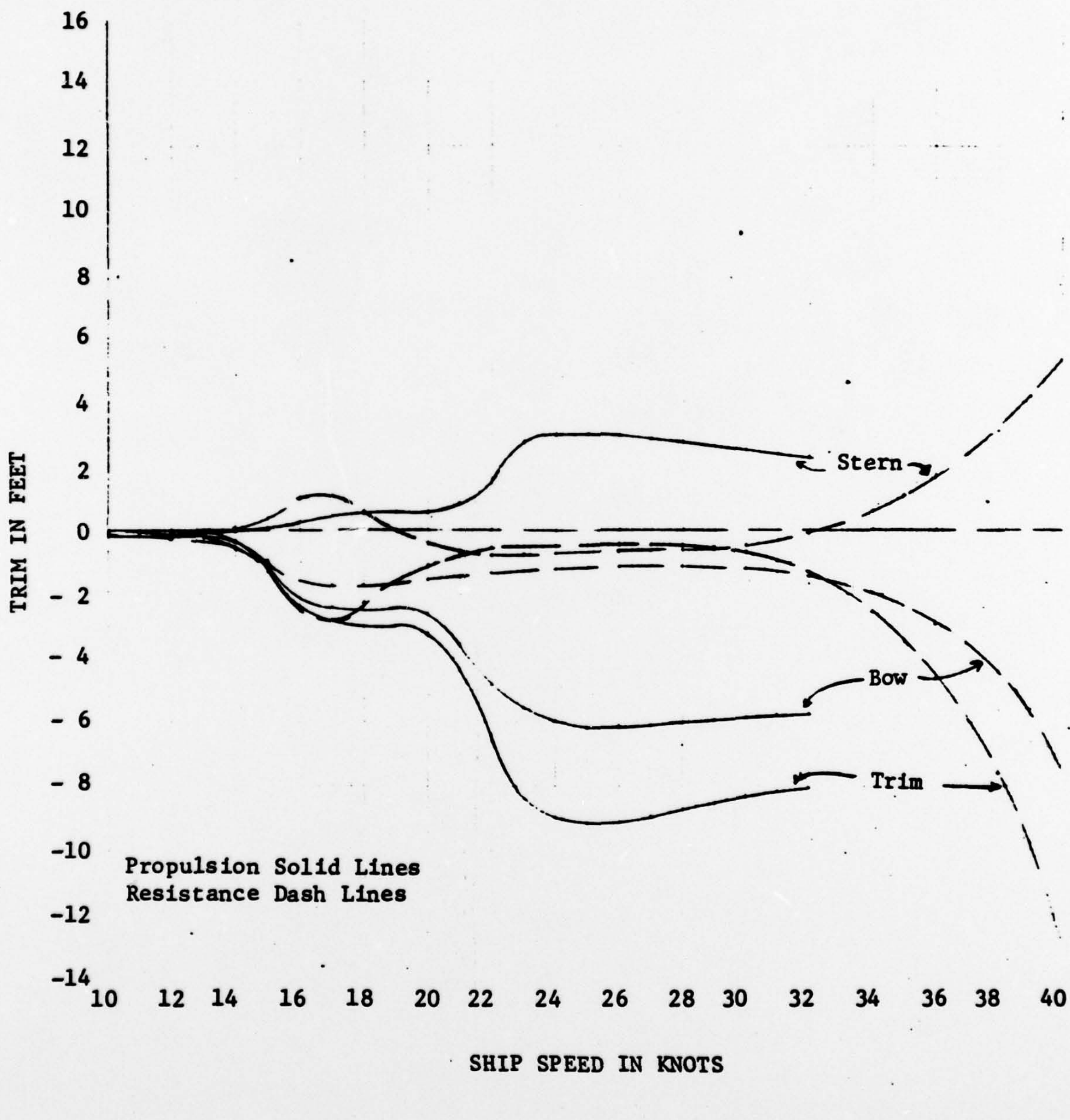


Figure 27 - Change of Level and Trim Characteristic Curves for SWATH IV Estimated from Resistance and Propulsion Experiments with Model 5287 at a 28-foot Draft (Free to Heave and Trim)

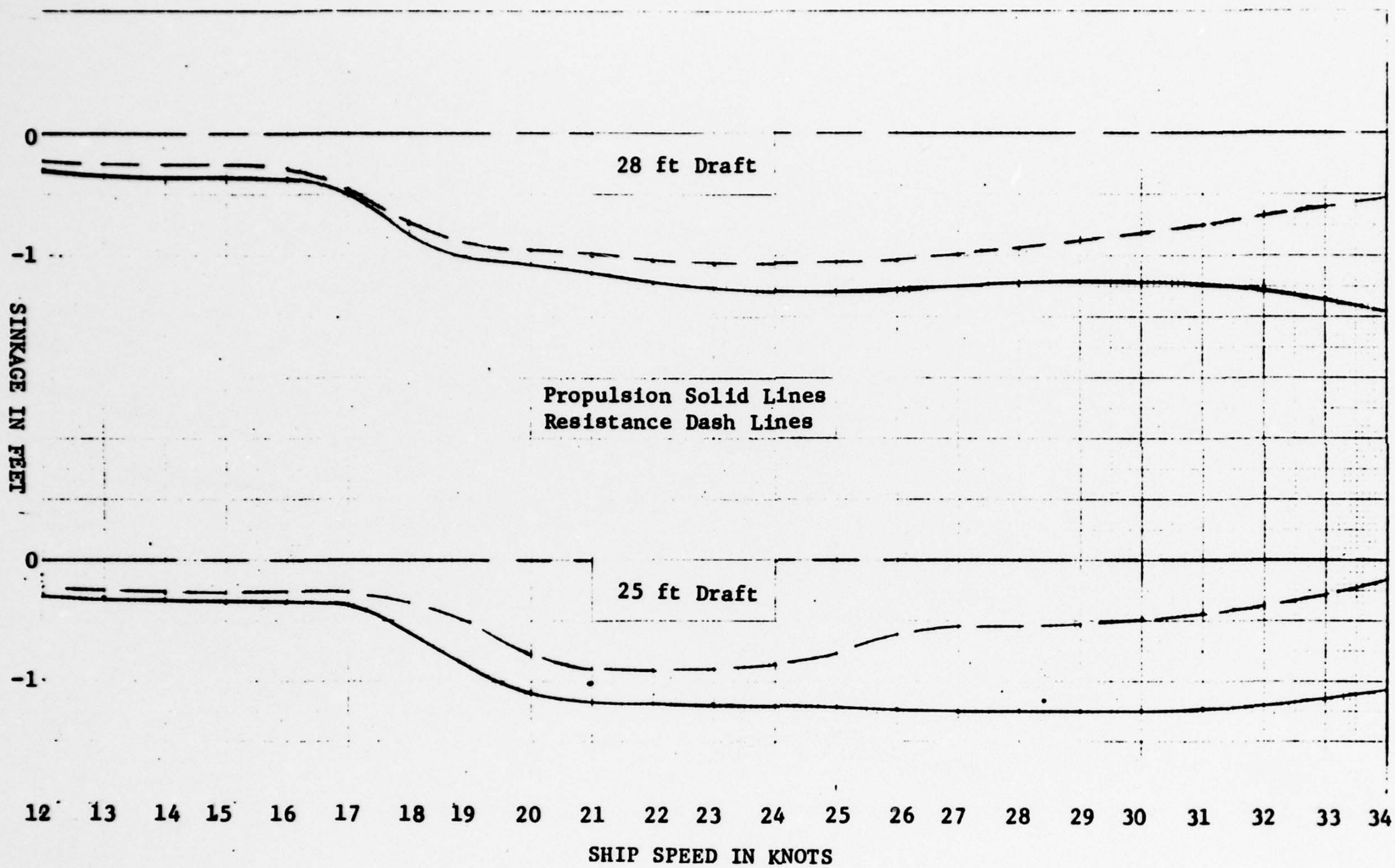


Figure 28 - Average Sinkage for SWATH IV
Estimated from Resistance and Propulsion Experiments
with Model 5287 at both the 28 and 25-foot Drafts
(Free to Heave)

TRIMMING MOMENT FOR SWATH IV DERIVED FROM RESISTANCE AND PROPULSION

EXPERIMENTS WITH MODEL 5287

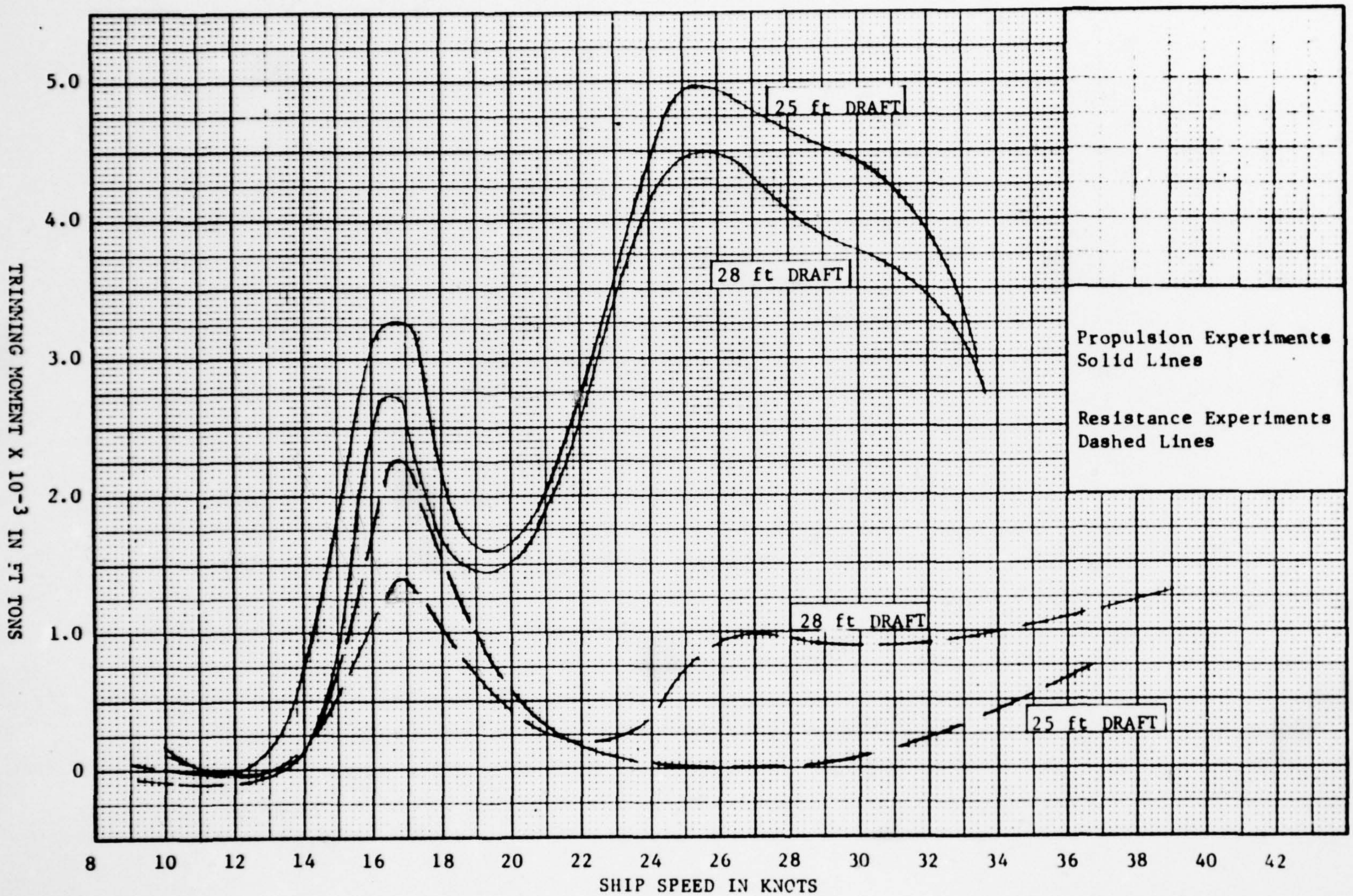


Figure 29

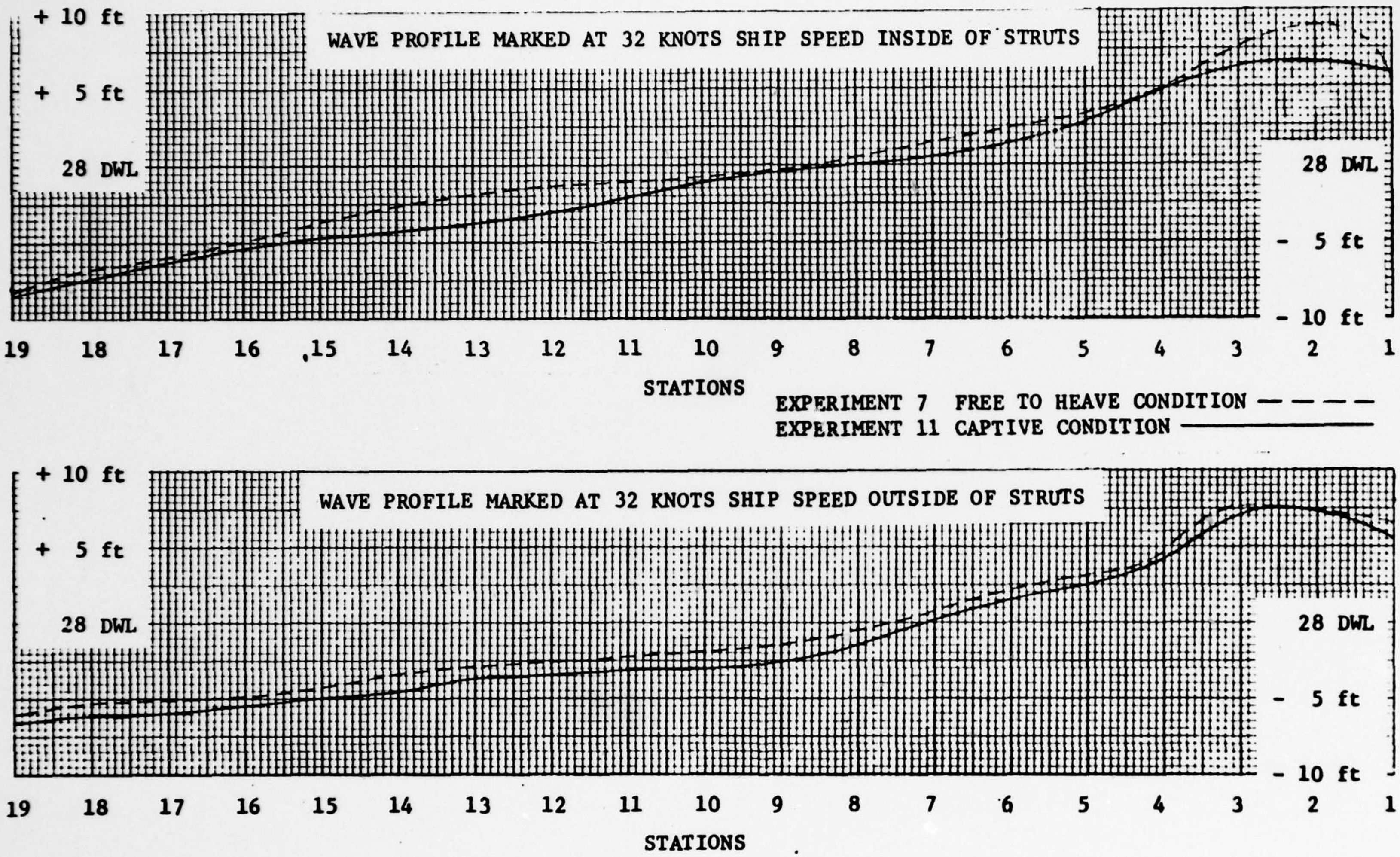
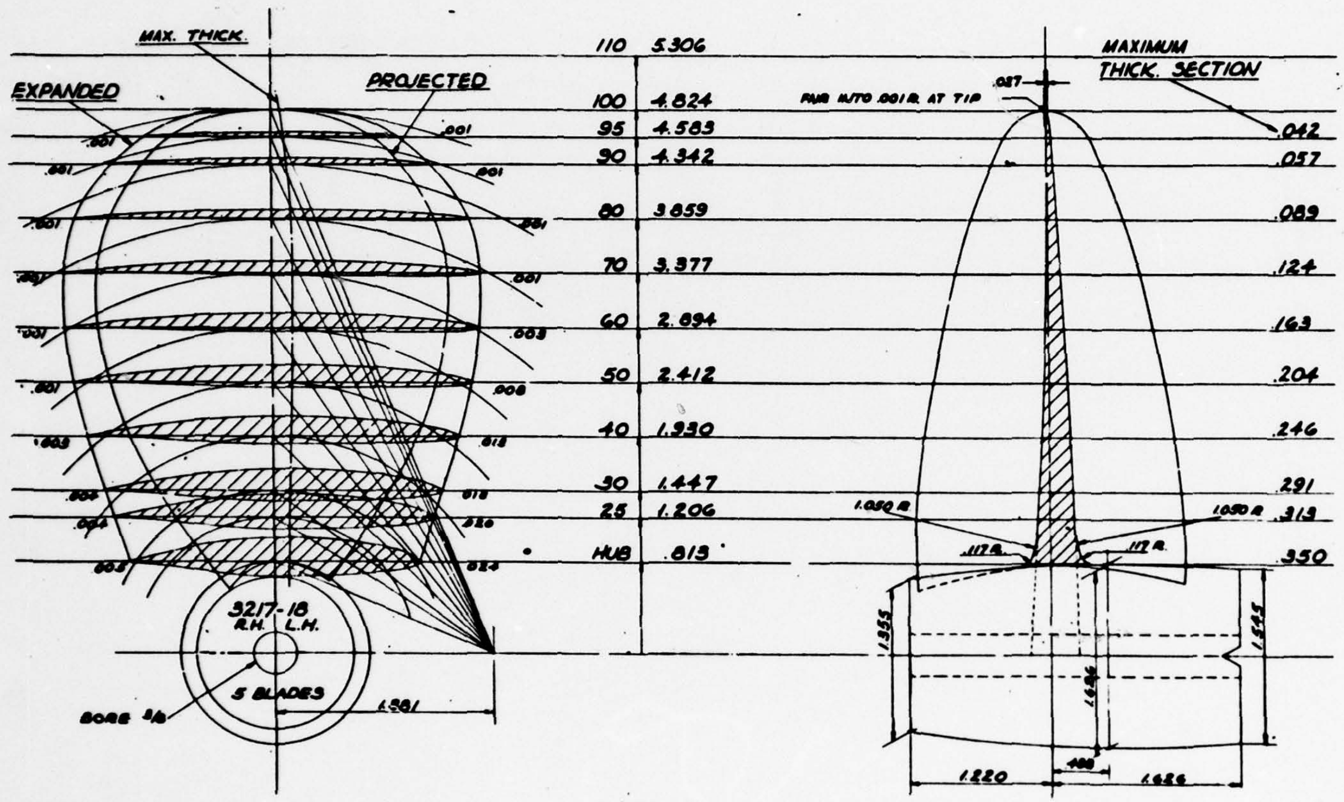


Figure 30 - Wave Profiles for SWATH IV Estimated from Resistance Experiments with Model 5287 at the 28-foot Draft (Free to Heave and Captive Conditions)

PROPELLER DIMENSIONS

NUMBER OF BLADES	5	MEAN WIDTH RATIO	0.319
DIAMETER (INCHES)	9.648	BLADE THICKNESS FRACTION	VARIABLE
PITCH (INCHES)	11.816	PITCH/DIAMETER	1.225
EXPANDED AREA RATIO	0.844	ROTATION 3217 (R.H.)	3218 (L.H.)



3217 R.H. 3218 L.H. 5 BLADES DIA. 9.648" PITCH PAT. BLOCK 11.816"

Figure 31 - Propeller Drawings and Dimensions Representing Model Propeller 3217 and 3218

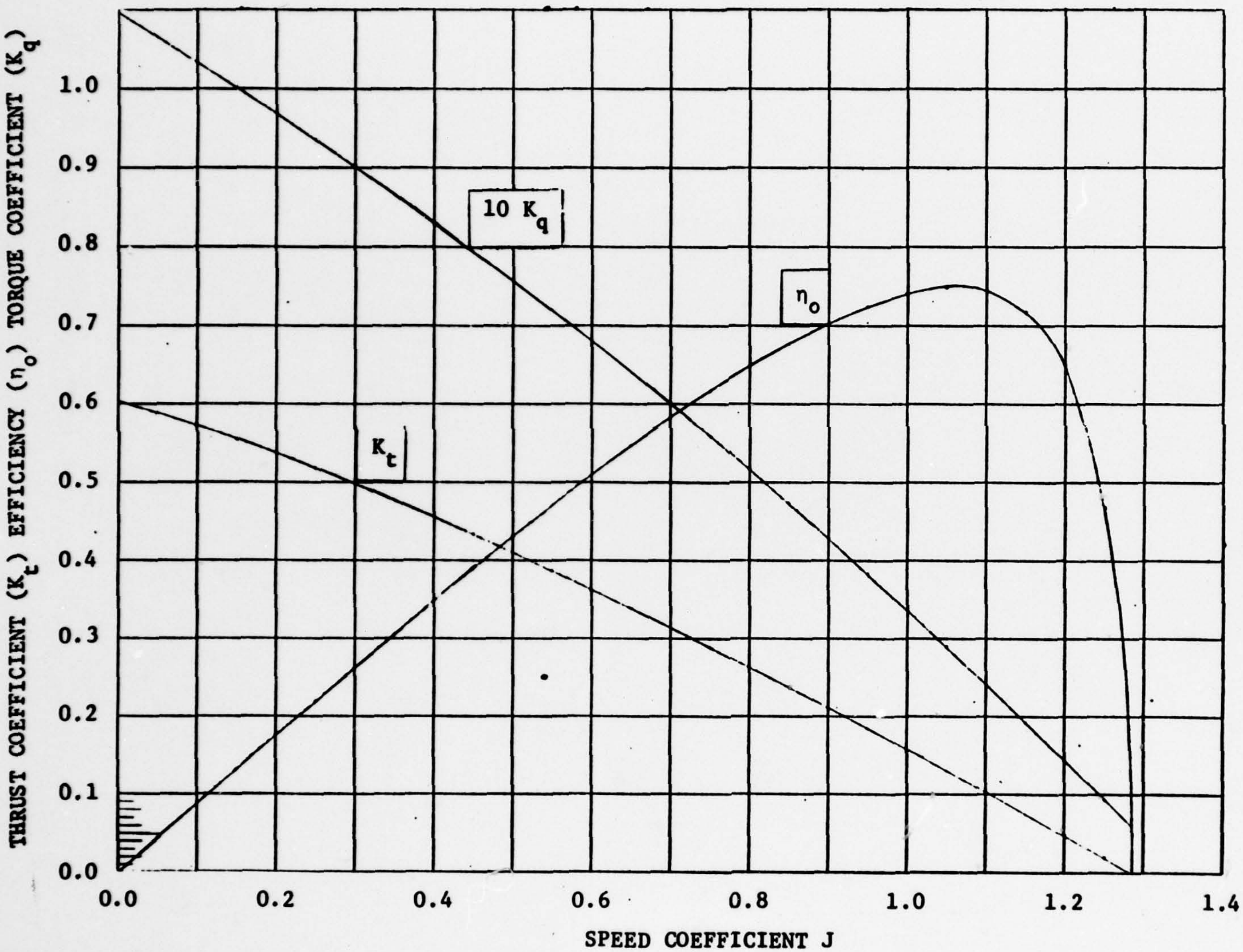


Figure 32 - Open Water Characteristic Curves for Model Propellers 3217 and 3218

PROPELLER DIMENSIONS

NUMBER OF BLADES	5	MEAN WIDTH RATIO	0.302
DIAMETER (INCHES)	7.623	BLADE THICKNESS FRACTION	0.054
PITCH (INCHES)	8.755	PITCH/DIAMETER	1.148
EXPANDED AREA RATIO	0.785	ROTATION 4415 (L.H.)	4416 (R.H.)

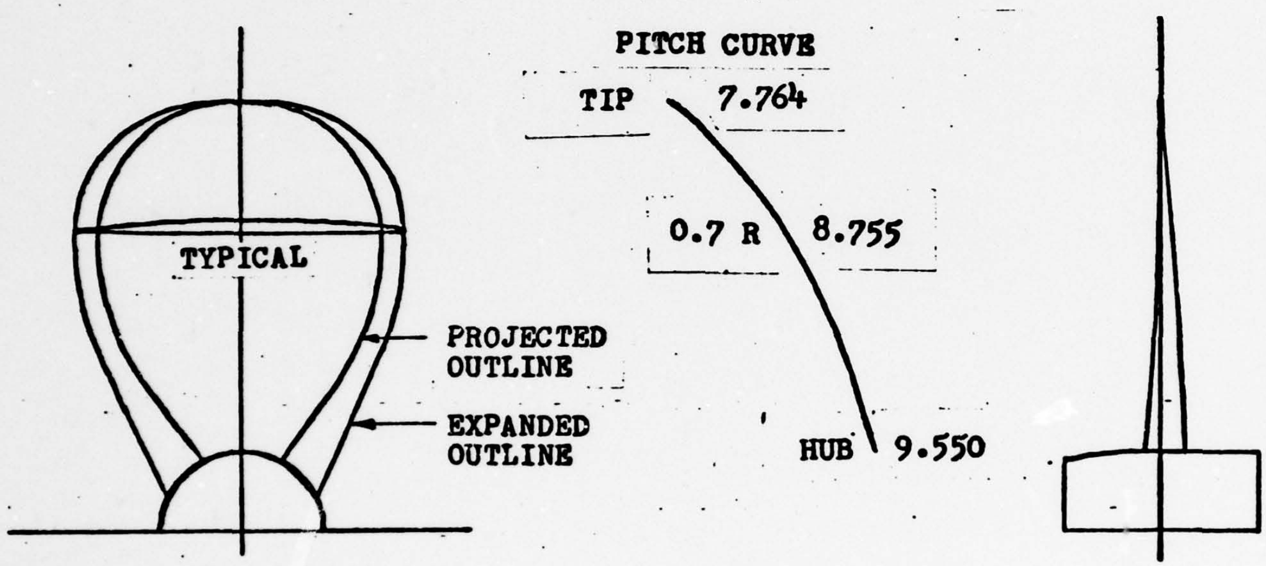


Figure 33 - Propeller Drawings and Dimensions Representing Model Propellers 4415 and 4416

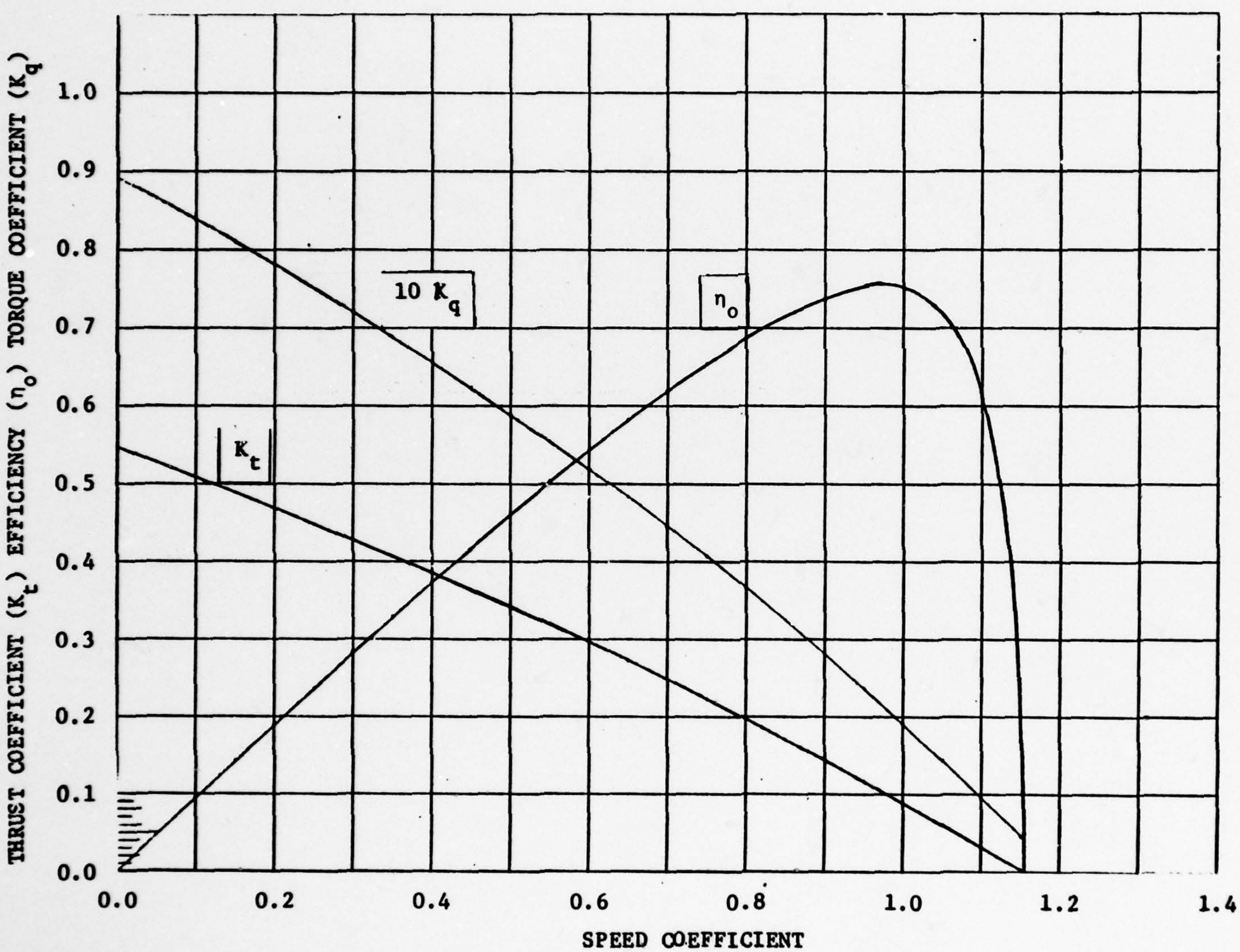


Figure 34 - Open Water Characteristic Curves for Model Propellers 4415 and 4416

PROPELLER DIMENSIONS

NUMBER OF BLADES	4	MEAN WIDTH RATIO	0.202
DIAMETER (INCHES)	11.34	BLADE THICKNESS FRACTION	0.060
PITCH (INCHES)	11.34	PITCH/DIAMETER	1.000
EXPANDED AREA RATIO	0.375	ROTATION 585 (R.H.)	586 (L.H.)

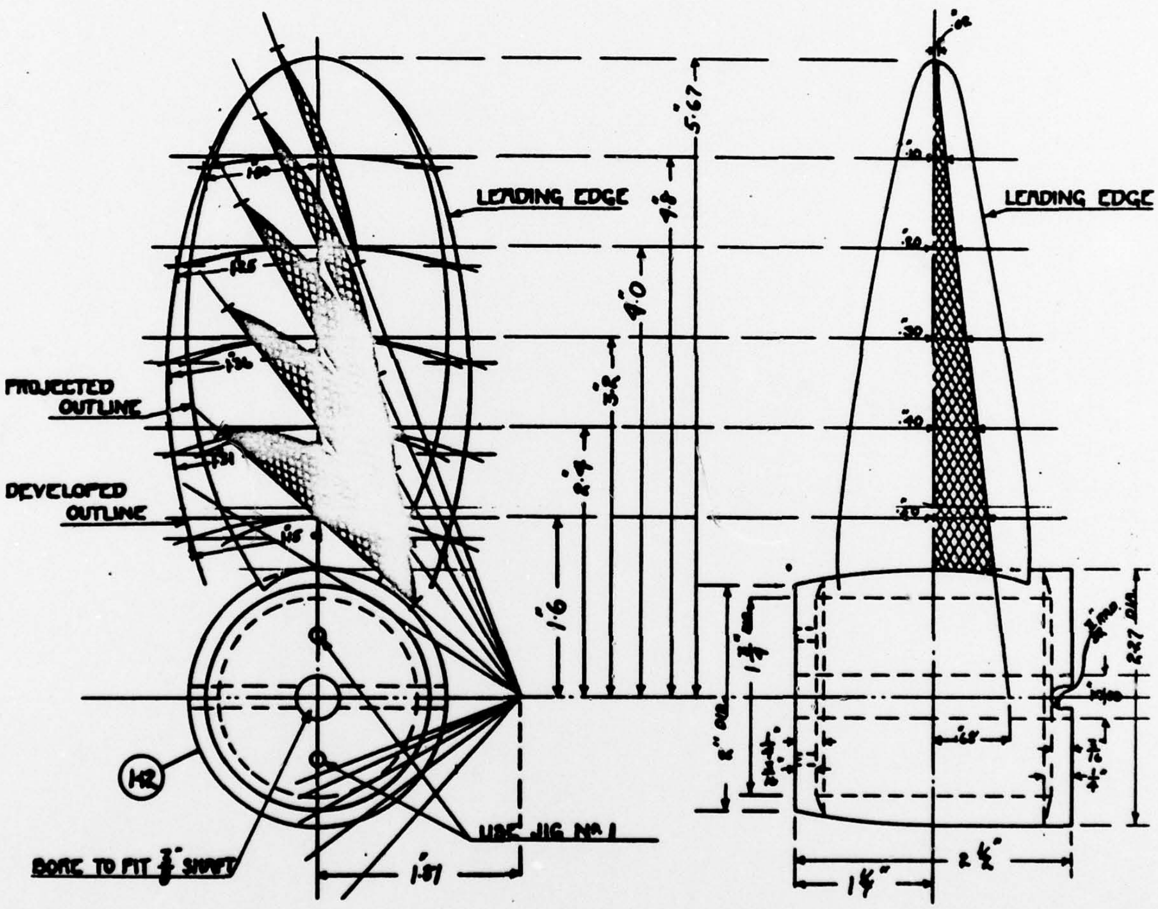


Figure 35 - Propeller Drawings and Dimensions Representing Model Propellers 585 and 586

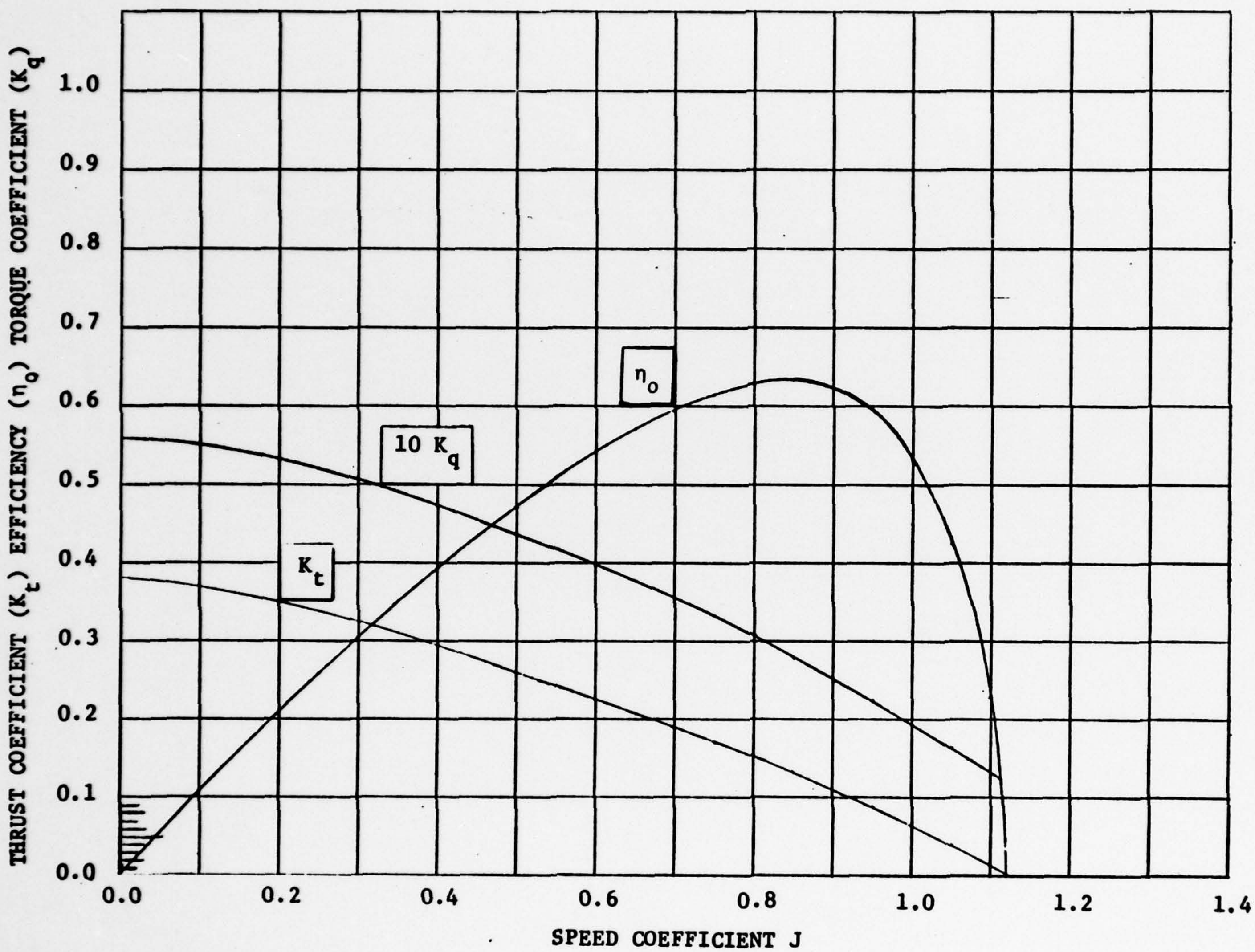


Figure 36 - Open Water Characteristic Curves for Model Propellers 585 and 586

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